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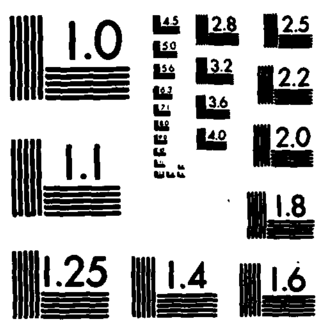


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# HOWITZER TECHNOLOGY ASSESSMENT STUDY

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NOVEMBER 1980

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER
WEAPON SYSTEMS LABORATORY
DOVER, NEW JERSEY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report reviews the problem of modelling the field artillery for the purpose of evaluating technology contributions. The needs in modelling from the design level, through the gun battery performance level, to the battle effectiveness level are discussed. A three-level hierarchy is proposed which will allow the translation of design changes into performance and effectiveness measures. A review of artillery effectiveness and the current modelling methodology is presented. Some observations and recommendations are made about ideal effective-

ness modelling. Extensive modelling and analysis techniques already exist at the armament design level; therefore, this report focuses on the important effects to be modelled at the performance level. A functional specification for a technology contribution model (TCM) is presented. The model is structured to accept gun subsystem design data as input and provide gun battery performance as output. The TCM specification calls for an event-oriented simulation consisting of seventeen functional modules. They portray the gun, its environment, and service requirements. Any combination of the seventeen functions can be used in a particular analysis. The TCM is intended to be the link between design and effectiveness. As such, it will provide outputs compatible with the AFSM battle models.

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# SECTION 1.0

# BACKGROUND & INTRODUCTION

## 1.1 BACKGROUND

In the fire support field artillery Mission Element Need Statement (MENS) of 23 May 1978 a number of system deficiencies were presented for the current field artillery system employed by the U. S. Army and Marine Corps. These include: vulnerability to enemy artillery counter battery fire and chemical biological and radiological warfare; the low field availability of field artillery systems; the labor intensive nature of today's artillery systems; the ability of field artillery systems to acquire and locate enemy targets is limited by both range and excessive errors; the excessive response time of field artillery systems from detection of target until the placing of rounds on the target; and the limited moving target capability of the field artillery system.

On the future battlefield, correcting these deficiencies of the field artillery system is essential to maintaining combined arms fire support superiority. The correction or improvement of the above mentioned field artillery deficiencies then becomes the objective of all large caliber weapon technology programs. Some of the technologies that are being worked on today which could have a beneficial effect on field artillery systems are the following: gun alignment technology; technologies which improve projectile handling and loading; fuze setting technologies; technologies which improve recoil mechanisms; and technologies which improve cannon wear. These above technologies would improve the performance of the howitzer in its current role and functions as part of the field artillery system. Other candidate technologies would improve the howitzer's contribution to the total field artillery system by expanding its existing functions or tactical capabilities. They include providing the howitzer an autonomous ability to locate its own position, establish its own azimuth reference, and perform on-mount technical fire control.

Each of these candidate technologies can be shown to in some way improve the performance of one or more howitzer functions. For example, automated fuze setting reduces errors and shortens loading time. Autonomous position location reduces the time required to emplace a battery. However, deficiencies and effectiveness are determined at a field artillery system level, not at a subsystem or even at a howitzer level. In an era of limited R&D and procurement budgets, it is essential that each of these, and future, technology opportunities be projected to their impact on field artillery system effectiveness. Only in this way can priorities on their development and application be established. The overall problem then becomes to quantify howitzer technology contribution to reducing field artillery system deficiencies.

The quantification of howitzer technology contribution has been attempted in the past with limited success. It has been attempted within the AFSM (Artillery Force Simulation Model). The AFSM models division/corps field artillery systems engaging comparable enemy forces. It is used to support yearly Legal Mix exercises to define field artillery tactics, numbers of required equipments, and the mix of each artillery element in European and other scenarios. In this role the AFSM has been refined to an accurate and useful model of the field artillery system.

In the past difficulty has been experienced in employing the AFSM to evaluate howitzer technology. Out of necessity the AFSM is modeled on a higher plan than that which is required to evaluate howitzer technology. It is more of a force engagement analytical model rather than a model which accounts for the performance of the various howitzer subsystems technology.

## 1.2 INTRODUCTION

This report presents the analysis and specification for an artillery Technology Contribution Model (TCM) which can be used to evaluate engineering changes in terms of system performance and interface with the AFSM programs for evaluation of battle level effectiveness. Section two of the report analyzes the need for the simulation, identifies the important effects which must be modelled, and shows how the model can be applied to the examination of operational requirements or evaluation of technical contributions. Section three is the specification which functionally defines the model structure and its interface with the technology areas and the battle models.

# SECTION 2.0

# TECHNOLOGY CONTRIBUTION MODEL REQUIREMENTS ANALYSIS

This section supports the technology contribution model (TCM) specification presented in Section 3. In this section is presented the rationale for the requirements presented in the specification as well as an analysis of the relationship between the TCM, artillery effectiveness assessment and technology and design assessment.

This section is organized into five major subsections: the need for TCM and study objectives (2.1); effectiveness of artillery (2.2); the important effects to be modelled (2.3); measures of design (2.4); and applications (2.5).

## 2.1 NEED AND STUDY OBJECTIVES

The need for a TCM evolves from consideration of several factors including:

- Operational mission needs of the field artillery
- Technology base program initiatives
- Current effectiveness methodology

This subsection will review each of these aspects and define the total study objectives.

### 2.1.1 Artillery Mission Needs

In the fire support field artillery mission element need statement (MENS) of 23 May 1978 a number of system deficiencies were presented for the current fielded artillery systems as employed by the U. S. Army and Marine Corps. Since correction of these deficiencies is the underlying objective for all of ARRADCOM's technology initiatives, a brief review of each is in order here.

Vulnerability to Attack from Enemy Artillery

Total vulnerability to counter battery fire is composed of three contributing elements: detectability, in particular while conducting fire missions; susceptibility to accurate and timely targeting; and finally the physical vulnerability of the artillery system components particularly ammunition and personnel.

Low Weapon Availability

The primary contributors being wear and erosion of the tube, reliability of the vehicular system and repair/maintenance of the entire system.

Labor Intensive

Maintaining a high rate of fire in the current artillery battery stresses personnel performance in ammunition handling, communications and gunnery. The goal is not to eliminate personnel from the battery but rather reduce the work load in critical areas to the point where high rates of fire can be sustained under conditions of fatigue and attrition.

Target Acquisition

The current artillery system has a limited capability to acquire and engage targets more than a few kilometers behind the FEBA.

Target Engagement Deficiencies

These include excessive target location errors, token capability to engage moving targets and excessive response time for all targets.

Inadequate Capability to Function in A NBC Environment

Because of inadequate alerting and protective systems.

While some of the deficiencies cited in the field artillery MENS relate directly to howitzer performance, most are system deficiencies involving all or most of the elements of the field artillery system including target acquisition, fire direction, gunnery, communications and all the other elements necessary for effective fire.

### 2.1.2 Technology Base Program

The large caliber weapons laboratory has a number of advanced technology programs ongoing which address one or more of the deficiencies noted above. Figure 2.1.2, while by no means exhaustive, illustrates some of the relationships between a sample of these technology initiatives and some of the system performance measures which they have the potential to improve. As an example, modular, consumable case, propellent charges have the potential to simplify the design and increase the speed and reliability of automatic loading mechanisms thereby increasing

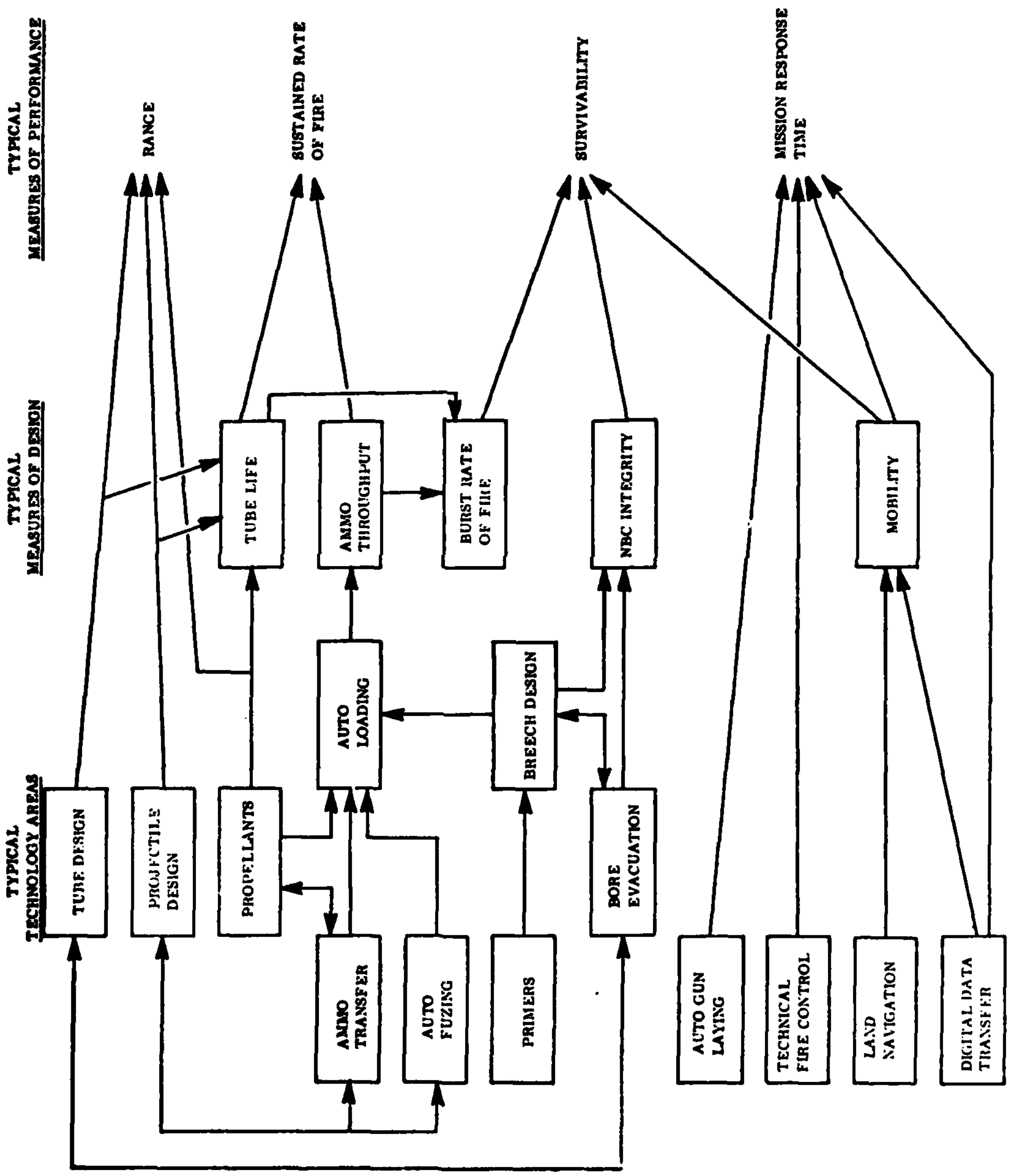



FIGURE 2.1.2
POTENTIAL TECHNOLOGY IMPACTS

the achievable sustained rate of fire. Conversely, the propellent and case materials have a direct impact on tube life through burning temperature and contaminants and therefore have an equivalent potential to limit that same sustained rate of fire performance measure.

In a similar way each of these technology initiatives impacts one or more related design areas and frequent trade-offs must be made between conflicting performance requirements. Also, the performance measures themselves as illustrated in Figure 2.1.2 are not directly related to the artillery MENS deficiencies. Those deficiencies are defined at an artillery system level and are impacted by many external factors beyond howitzer performance including; target acquisition, communications, tactical fire control, etc.

Several of these technologies have been integrated in a series of howitzer test beds for field evaluation. Test bed number one emphasized the function of automated gun laying with an objective of one-man operation and the total elimination of gross gun laying errors. Test bed number two employed conventional manual gun laying but incorporated a land navigation system increasing the tactical mobility of the howitzer. Test bed number three now in the planning stages will integrate the features of test beds one and two adding a tube reference, onboard technical fire control and an onboard data link in TACFIRE message format so that target acquisition sensor data can be translated directly to tube deflection and elevation. Field tests of these test bed systems have provided valuable engineering data in areas such as response time, accuracy of gun laying, accuracy of rounds on target and crew work load requirements. This data is still partial and incomplete relative to the artillery system effectiveness goals established by the field artillery MENS, primarily because it is limited to the howitzer itself and its immediate communication links. It does not include the impact of the other elements of the artillery system with realistic combat loadings such as target acquisition, tactical fire control and ammunition resupply. However, this is not to say that this test bed field test data is not extremely valuable and essential in formulating future technology goals. Rather, as with all real world systems, the capability for conducting live tests in a totally realistic combat environment is prohibitive.

Each of the candidate technologies can be shown by subsystem performance analysis or limited field testing to in some way improve the performance of one or more howitzer functions. Returning to Figure 2.1.2, automated fuze setting can be shown to increase the peak rate of fire and reduce manpower requirements. This in turn should increase the number of target kills and battery survivability. However, when the factors of ammunition resupply and handling, reliability and maintenance are considered the capability for sustained rate of fire, depending upon design characteristics, may change very little.

In an era of limited R&D and procurement budgets it is essential that each of these technologies and future opportunities be projected to their impact on field artillery system effectiveness. Only in this way can integrated technology performance goals be established and priorities set on their development and application. The overall problem then becomes the development of a methodology to quantify howitzer technology contributions to improving field artillery system effectiveness.

### 2.1.3 Current Effectiveness Methodology

The standard analytic tool for assessment of artillery effectiveness is the Artillery Force Simulation Model (AFSM). The AFSM models division/corps field artillery systems engaging comparable enemy forces. It is used to support legal mix exercises to define field artillery tactics, force levels and mixes in various ground combat scenarios. In this role the AFSM has been refined to become an accurate and useful model of the field artillery system.

The AFSM consists of three major (and numerous minor) elements. Those major elements are:

- Resource Allocation - An externally generated target list is operated on by TACFIRE algorithms to develop battery/target assignments. Realistic delays are assessed in this process.

- Asset Inventory - The resource allocation element draws on a "real time" asset inventory. After initialization this inventory is continuously adjusted to account for failures, attrition, movement, ammunition flow and current fire missions.

- Target Effects - The effect of an assigned fire mission is computed by the lethal area concept and data from the Joint Munition Effectiveness Manual (JMEM) for HE and ICM rounds.

There are several operating variants of the AFSM in use throughout the Army with varying emphasis on target acquisition, Red counterbattery fire, etc. However, all the variants are basically as described above models of Blue artillery forces vs. Red targets and counterbattery. They are not full two-sided models. Further, all variants model conventional battery tactics and deployments.

The basic measure of effectiveness extracted from the AFSM model is:

Effectiveness = Number of Casualties x Military Worth

Casualties is the value computed by the target effects section of the AFSM model using JMEM methodology. When a unit under attack has been reduced by 50% it is counted as a total kill. The military worth factor is a subjective multiplier which attempts to reflect both the intrinsic military value of the personnel or materiel killed and their immediate value in the combat; that is, the closer the kill to the FEBA the higher military worth. The recent trend by AMSAA has been to ignore the subjective value of military worth and simply to count kills. While the other military effects of artillery fire, generally labeled suppression, are recognized as important, the difficulty in agreeing on the quantifiable measure of this effect has led to its being eliminated as an effectiveness measure in AFSM and other battle models.

While other statistics are extracted from AFSM (targets serviced, targets dropped, etc.) for practical purposes the prime measure of effectiveness in the AFSM model is total number of kills. The model affects the number of kills in two ways. First, delays in the resource allocation process (tactical fire control, communication, technical fire control and battery availability) can, and frequently do, exceed target life. When a target life is exceeded, that target is dropped and potential casualties are reduced. Second, when fire is delivered on a target, the number of casualties produced is almost exclusively a function of round type, number of rounds, range (angle or fall), and target type/posture.

Previous attempts to use the AFSM model to measure the marginal utility of technology advances have resulted in insensitivity to any technology improvements. This insensitivity to technology should not be surprising considering the original AFSM objective. To quote from the AMSAA users manual for AFSM

> "...AFSM was developed in 1974-1975 to enhance the U. S. Army Material Systems Analysis Activity's (AMSAA) capability to evaluate the performance of artillery force mix alternatives against RED threat scenarios..." (Underlining not in original text.)

The technical reasons for this insensitivity as concluded from the above discussion are:

1. The single effectiveness parameter, casualties, is heavily dominated by munitions effectiveness.

2. Other effects of the artillery on opposing maneuver forces, primarily suppression, are not quantified.

3. The AFSM models conventional artillery deployment and tactics while many of the new technology initiatives are better suited to alternative tactics (*shoot and scoot, dispersed formations, etc.*).

### 2.1.4 Study Objectives

This assessment of the relationship between artillery mission needs and technology initiatives led to the conclusion that an element was missing in the analysis methodology. In the Review of Army Analysis (April 1979) Mr. David Hardison *et al.* recommend a hierarchal structure of simulation tools to provide breadth, detail and visibility in Army analysis. Figure 2.1.4, adapted from that report, illustrates this concept. In the case of artillery fire support, a TCM would become the "item system simulation", and AFSM would aggregate artillery effectiveness at the division/corps level for input to a division/corps combined arms model such as DIVWAG.

In summary, the task objectives of this study are:

1. Review the artillery technology base and missions and outline an overall methodology which will relate the performance of technology alternatives to artillery system effectiveness.

2. Review the existing models employed in the artillery community and assess their utility within structure.

3. Prepare the specification for a technology contribution model (TCM) which, when developed, will link technology design data to battle level effectiveness models.

4. Prepare a development plan for the technology contribution model.

## 2.2 THE EFFECTIVENESS OF ARTILLERY

In order to develop a coherent methodology for the quantitative assessment of howitzer technology contributions to artillery system effectiveness it is first essential to understand the mission of the field artillery and the ways in which relative capability to accomplish those missions can be quantified. That, in summary, is the objective of this subsection, and it is a vital objective because it establishes the context within which technology contributions will be measured.

### 2.2.1 Artillery Missions

The missions of artillery as part of the combined arms team can be categorized in several functional ways dealing with direct and indirect support, types of

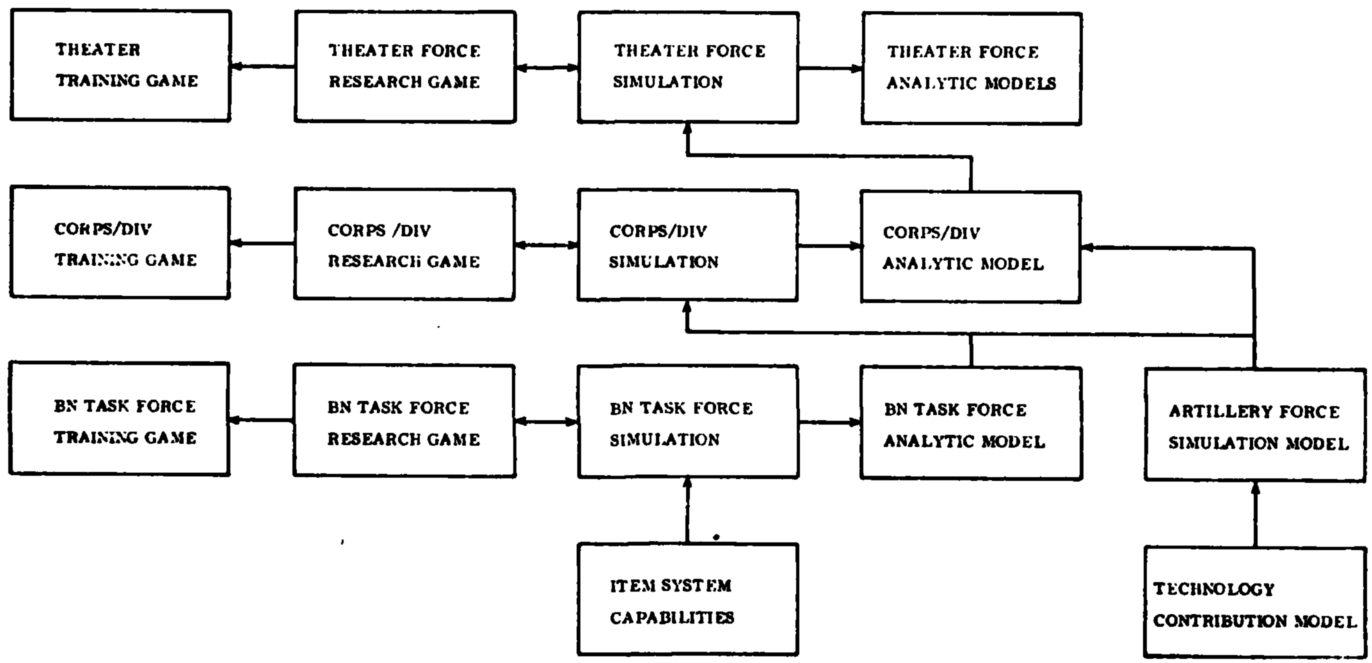



FIGURE 2.1.4

A CONCEPTUAL STRUCTURED SET OF SIMULATIONS, GAMES, AND ANALYTIC MODELS INCORPORATING THE TCM

fire missions or targets. However, perhaps the most useful insight into those functions expected of the artillery as part of the combined arms team is given in Army FM 100-5. The doctrine presented in FM 100-5 reflects those tactics believed to be effective in defense of Western Europe against numerically superior Warsaw Pact forces. In the following paragraphs we will paraphrase the doctrine presented with emphasis on the stated and implied functions of artillery within this operational doctrine.

Move to Concentrate Forces

Corps and division commanders must decide exactly when and where they will concentrate their forces based upon the results of intelligence. They must also decide how much force will be required to cope with the enemy attack within the terrain and space limitations of the defensive area. As a rule of thumb, they should not be outweighed by more than three to one in terms of combat power. With very heavy air and field artillery support on favorable terrain, it may be possible to defend at an numerical disadvantage of something like five to one for short periods of time. During this period reserve and flanking maneuver forces can be brought to bear. To defend against break-through tactics, division commanders must not only concentrate at the right time and place but they also must take risks on the flanks. Thus, for example, division commanders must be willing to concentrate fire power and up to six to eight of their maneuver battalions on 1/5 of their front to meet break-through forces of twenty to twenty-five battalions. Concentration of field artillery is equally important. Unlike tanks and infantry field artillery fire can often be concentrated without moving batteries. In extended areas, however, field artillery also must be moved to position within range of the enemies' main effort. Division commanders would certainly move at least three of their four battalions and would expect to be reinforced by the bulk of the Corps artillery.

Fight as a Combined Arms Team

Brigade and battalion commanders must organize their forces for combat according to the size and density of the enemy attack, the characteristics of the terrain to be defended, and the mix of defending units. As friendly units converge on the critical battle site, the battalion and brigade commanders commit them to combat according to their weapons' capabilities and the movement of the enemy force. The first increment of combat power available is usually the mass fires of all field artillery in range. Even if the artillery fire does not destroy large numbers of armored vehicles, it buttons up tanks and reduces their effectiveness greatly (as much as 50%). Thus the tanks cannot maneuver as easily or use the terrain as well, nor can they see defending weapons as well and thus cannot engage or suppress them as effectively. Enemy infantry cannot dismount to attack dismounted antitank weapons.

Artillery can also smoke the over-watching positions covering the enemy attack.

The role of field artillery in the defense can be summarized as follows:

- Destroy the momentum of offensive maneuver forces by planned mass fires, while defensive maneuver forces are committed.
- Disrupt the continuity of enemy combined arms formations by separating the infantry from tanks.
- Scattering mines in the path of maneuver forces to stop them where our fires can destroy them.
- Destroy smoke or suppress antitank weapons and enemy tanks in over-watch positions.
- Suppress enemy tanks by causing them to button up, get off roads, slow down and lose their ability to bring fire rapidly on defenders.
- Suppress or destroy enemy artillery and mortars by counterfire.
- Isolate parts of the battle field with a variety of munitions so that counterattacks may be mounted against exposed and weakened attacking forces.

The role of field artillery in the offense can be summarized as follows:

- By planned mass fires at the critical time and place.
- Destroy or suppress enemy antitank guided munitions.
- Destroy or suppress enemy infantry.
- Suppress enemy tanks by causing them to button up or by smoking their positions, or, in the future, by destroying them with precision guided munitions.
- Destroy or suppress enemy artillery and mortars by counterfire.
- Destroy or suppress enemy forward area air defense to assist friendly close air support.

It is interesting to note the heavy emphasis given the function of artillery to suppress enemy maneuver forces or artillery at critical times and in critical places during the battle. This stresses the role of the artillery as both an offensive and defensive force multiplier on the effectiveness of the maneuver forces in immediate contact along the FEBA. It is clear that experienced commanders believe that heavy artillery support can increase the effectiveness of defensive forces from the ability to defeat a three to one ratio to the ability to defeat a five to one ratio for at least short periods of time. A similar force multiplier effect must exist for offensive operations as well.

### 2.2.2 Effectiveness Measures

With the doctrine of FM 100-5 as background let us consider in a slightly analytic sense the mission and effectiveness measures of artillery. Figure 2.2.2 presents in the form of an influence diagram the interfaces that exist between two combined armed forces. Both sides are composed of three major elements. The maneuver forces on both sides are those elements of infantry and armor in direct contact on the FEBA. It is the relative success or failure of these opposing maneuver forces in gaining or holding ground that is the ultimate measure of battle effectiveness.

The doctrine presented in FM 100-5 clearly indicates, however, that local advantage in the area of an attempted offensive breakthrough is critically important in determining the battle outcome. This advantage can be established by mobile maneuver forces which directly change the force ratio at a given point and time. It can also be directly influenced by the fire support element by reducing the effectiveness of the opposing maneuver force at critical times and at critical locations during combat.

The fire support element is composed not only of tube artillery, but also rocket artillery both guided and unguided and air support elements. Therefore, the missions of any single element of this fire support team must consider the complementary capabilities of the other team elements. It is essential, then, that we consider the way in which artillery fire support can be employed against the opposing forces in total and understand the mechanisms by which the success of this fire support influences the battle outcome.

#### 2.2.2.1 Fire Against Maneuver Forces

Figure 2.2.2.1 illustrates the role of the friendly fire support elements against the opposing maneuver forces. Clearly the objective is to reduce the effectiveness of the red maneuver forces relative to their immediately opposed blue forces

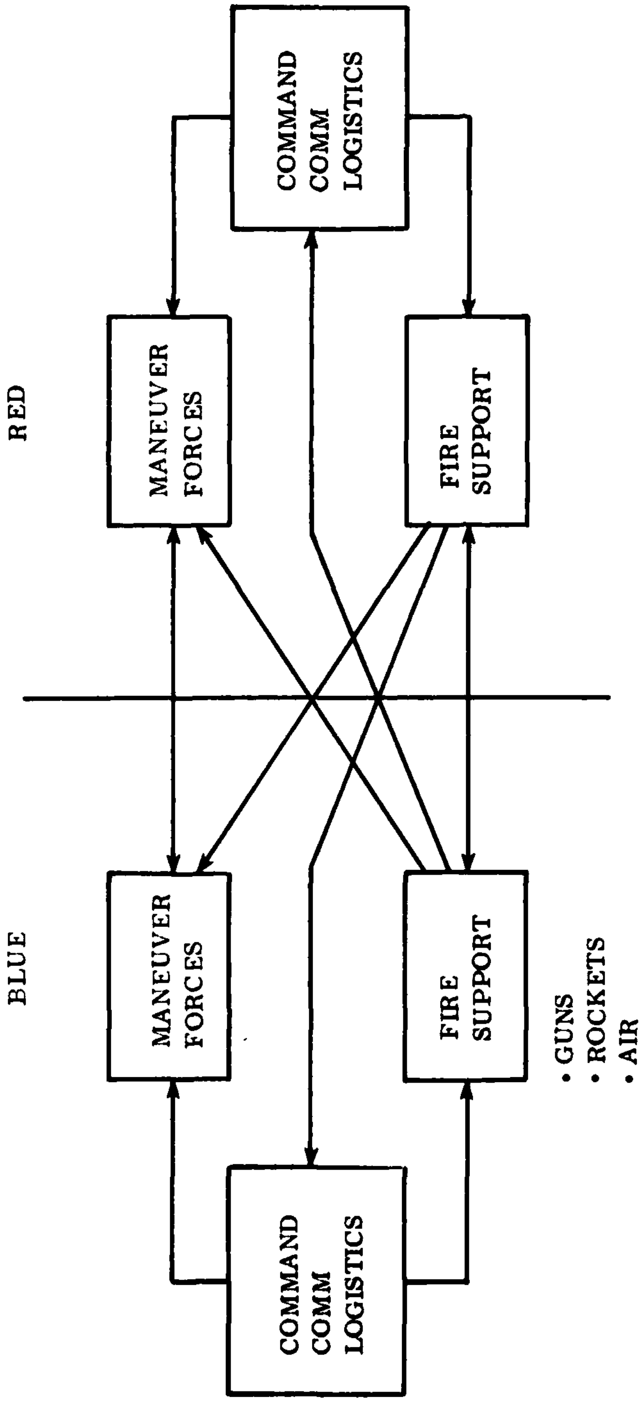
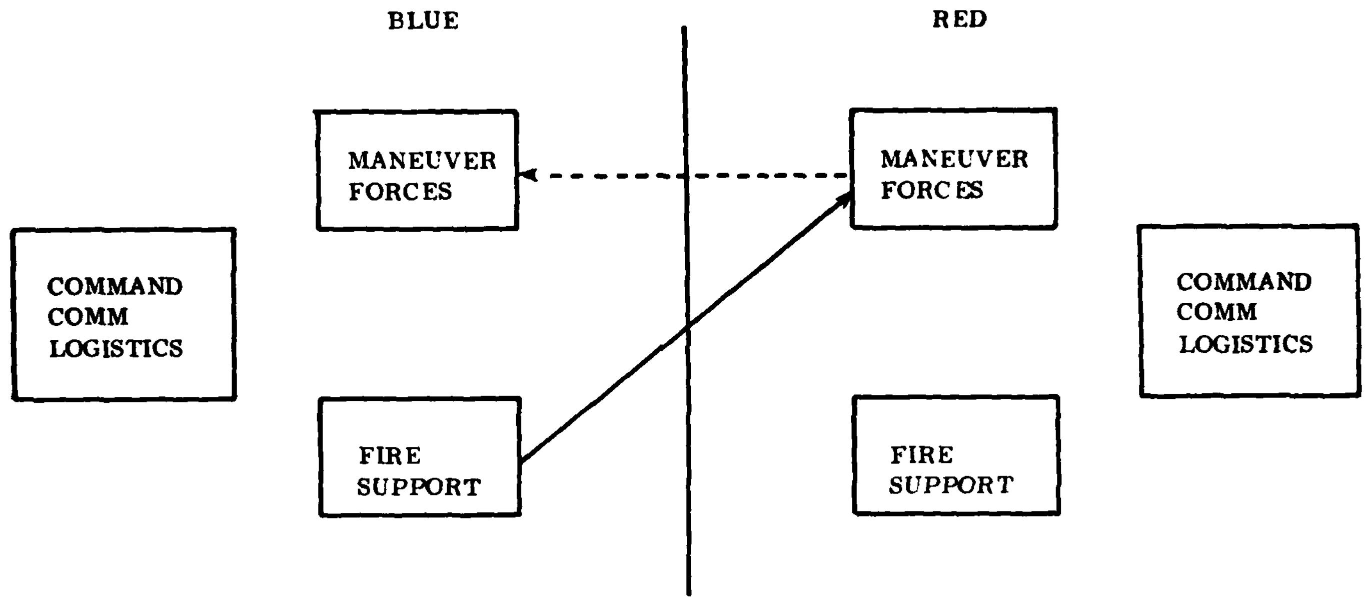



FIGURE 2.2.2
BATTLE INTERFACES




REDUCE EFFECTIVENESS OF MANEUVER FORCE

- PERMANENTLY - KILL
- TEMPORARILY - SUPPRESS

COMBAT MOE'S

- NUMBERS KILLED
- AREA, TIME & LENGTH OF SUPPRESSION

FIGURE 2.2.2.1

FIRE AGAINST MANEUVER FORCES

at a specific time. The effectiveness of the maneuver forces can be reduced in two ways: first, permanent reduction by personnel or materiel casualties; secondly, by temporarily reducing the mobility, visibility or fire effectiveness of armor or infantry.

It is clear from the doctrine of FM 100-5 that whether we are considering casualties or suppression as an effectiveness measure, the time and place at which kill or suppression took place is an important factor in true combat effectiveness. For example, a casualty occurring at the point of breakthrough early in an offensive operation should have significantly higher weight than an identical casualty occurring at a non-critical area of the FEBA, or long after the breakthrough has occurred. In one sense this concept is an extension of the concept of military worth but it encompasses two additional factors beyond the range from FEBA considered in military worth terms. Those factors are time and location of the casualty relative to the time and location of attempted breakthrough.

This extended concept of weighted casualties as a measure of effectiveness should exhibit greater sensitivity to advanced howitzer technology. Inherently it will be more responsive to:

- Extended range which allows lateral massing of fire.
- Response time.
- The ability to surge firing rates over the period of a few hours.
- The ability to elude counterbattery fire and conduct fire missions during the critical breakthrough period.

However, the whole concept of kills as an artillery measure of effectiveness needs to be placed in some historical perspective. Retrospective studies of World War II and Korean War combats all tend to indicate that numerical casualties are measured in tons of artillery fire per casualty. These numbers vary greatly depending upon offensive or defensive situations, the degree of cover or defensive preparation available, personnel densities and numerous other factors. However, on an absolute scale the casualties produced by high explosive fragmentation rounds were never very high. The introduction of improved conventional munitions substantially increases the effective lethal area per round against the personnel, but this trend is countered by the fact that modern mechanized infantry will be exposed to the effects of conventional munitions for a much smaller fraction of the total combat time.

The vulnerability of materiel (artillery pieces, armored vehicles and tanks) has always been low, requiring a direct or near direct hit for effective kill. FASCAM rounds will not appreciably increase the number of materiel kills since their primary purpose is to deny ground for enemy maneuver. The only round which can appreciably affect the ratio of number of kills to rounds fired is the cannon launched guided projectile (CLGP). From this perspective, it is not surprising that the AFSM primary measure of effectiveness, has proven to be insensitive to artillery technology initiatives. In fact it may be a farily accurate representation of the true situation.

Yet major ground battles have been won in which artillery has been credited by commanders with playing a decisive role, even when the number of direct casualties produced to tons of ammunition fired was fairly small. Therefore, casualties must be regarded as suspect as the sole or even the primary measure of artillery effectiveness. Casualties as a measure of effectiveness has one distinct virtue. Mature analytical methods exist which can quantify kills with reasonable accuracy. The lethal area techniques represented in the Joint Munitions Effectiveness Manual are analytic projections of experimental data which can provide usable estimates of the likely number of casualties for conventional and improved conventional munitions against a variety of targets. The same statement cannot be made about the other effects of artillery against maneuver forces, primarily suppression.

Several analytical approaches to quantifying suppression have been developed but all suffer from two major drawbacks, the number of dependent variables involved and the psychological basis of the effect. The dependent variable factors include the combat experience of the troops being suppressed, the density and area coverage of fire, type of munitions, the degree of cover and protection available, the fatigue level and morale of the troops involved and other factors too numerous to catalogue. Secondly, the degree and length of time within which the combat effectiveness of the suppresssed forces is reduced is an arguable psychological parameter. The result of this uncertainty has been to eliminate suppression as a measure of artillery effectiveness and rely solely on kills while historical evidence suggests that the priority for artillery should be just reversed.

Innumerable anecdotal examples of the effects of suppression exist. Possibly the most extreme is the Russian offensive at Stalingrad in January 1943 when 7,000 Russian tubes and airstrikes reduced three German divisions to total combat ineffectiveness before the Soviet armor and infantry broke through. However, by AFSM criteria (50% casualties) these German divisions would not have been counted as attrited. While this example is extreme it serves to illustrate the point that artillery effectiveness is likely to remain insensitive unless its impact as a suppressor or maneuver force multiplier is accounted for.

### 2.2.2.2 Suppression

Given all the previous work that has been done, it is unlikely that an absolute measure of suppression will be derived on which any general agreement can be reached. However, relative measures of suppression are possible and may, in fact, be the only valid approach to this highly subjective factor.

Consider for a moment the simplified example shown in Figure 2.2.2.2 as a model for two significant effects of maneuver force suppression. The figure illustrates the hypothetical situation of three red maneuver battalions attempting a breakthrough over a narrow frontal area defended by a single blue maneuver battalion. This breakthrough is supported by red force artillery fire against blue forces at the point of breakthrough as well as flanking blue forces. The fire delivered at the point of attempted breakthrough attempts to increase the force effectiveness of the three attacking battalions.

FM 100-5 suggests some quantitative measures of this effect. It is stated that as a rule of thumb the defending forces should not be outweighed by more than three to one in terms of combat power. This suggests a "break even" offensive to defense force ratio with roughly equivalent fire support on both sides. FM 100-5 further suggests the possibility that with heavy fire support it may be possible to defend, for short periods of time, with numerical disadvantages up to five to one. Admittedly these are rough "rules of thumb" and will not hold true under every conceivable condition. However, they are based on military experience and judgment and it is not likely that any simulation no matter how elaborate is ever likely to produce more justifiable criteria. Assuming these types of simple numerical criteria, it becomes quite possible to measure the relative effectiveness of opposing artillery forces in providing the fire support necessary to influence the combat outcome of the critical point of breakthrough.

The quantification of relative suppression in the localized breakthrough area could be handled as a logical extension of the concept of lethal area.

$$\text{FIRE SUPPORT RATIO} = \frac{\text{WEIGHTED SUPPORT FIRE}_{\text{Blue}}}{\text{WEIGHTED SUPPORT FIRE}_{\text{Red}}}$$

WHERE

$$\text{WEIGHTED SUPPORT FIRE} = \sum_{x_1}^{x_2} \sum_{t_1}^{t_2} \sum^{\substack{\text{Round/}\\\text{Target}\\\text{Types}}} \text{TARGET COVERAGE} \times \text{\# ROUNDS}$$

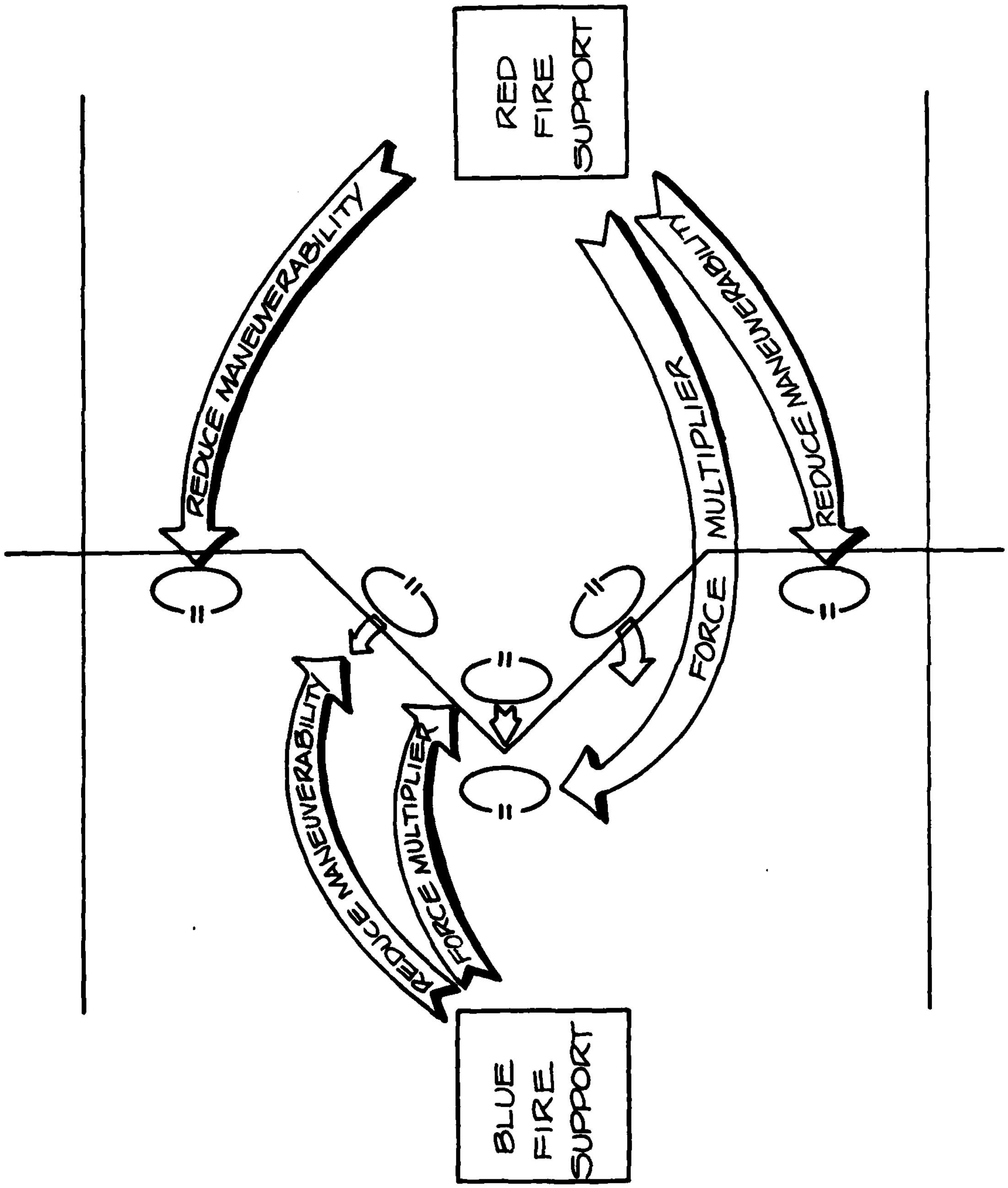



FIGURE 2.2.2.2
SIMPLIFIED SUPPRESSION MODEL

WHERE

$x_1, x_2$ = PHYSICAL EXTENT OF BREAKTHROUGH AREA

$t_1, t_2$ = TIME EXTENT OF BREAKTHROUGH

This formulation accounts for most of the relevant effects including offensive or defensive posture, volume of fire, type of round, timeliness of fire, and placement of fire. It can be argued that the result is "just a ratio", but that ratio should have meaning to an experienced combat commander and is a quantitative evaluation factor that should reflect the impact of many of the technology initiatives available to the artillery. If there are errors in the quantification of either the numerator or the denominator of this ratio, as there probably are, at least the errors are uniformly applied to both sides and a valid relative measure of the effects of the fire support on both maneuver elements has been achieved.

The effect of red force fire support on the flanking blue forces is a suppression effect which also must be considered. Clearly, the intent of this fire is to limit the ability of the flanking battalions to reinforce at the point of breakthrough. What is required in this case is the modeling of the relationship between transit speed of the reinforcing maneuver force vs. the type and volume of suppressing fire being delivered. For example, with mechanized infantry it is clear that FASCAM will be more effective at slowing movement than will conventional high explosives and either of these will be more effective than no suppressing fire whatsoever. The net effect of this suppressive fire is to delay augmentation of the blue force ratio at the point of attempted breakthrough.

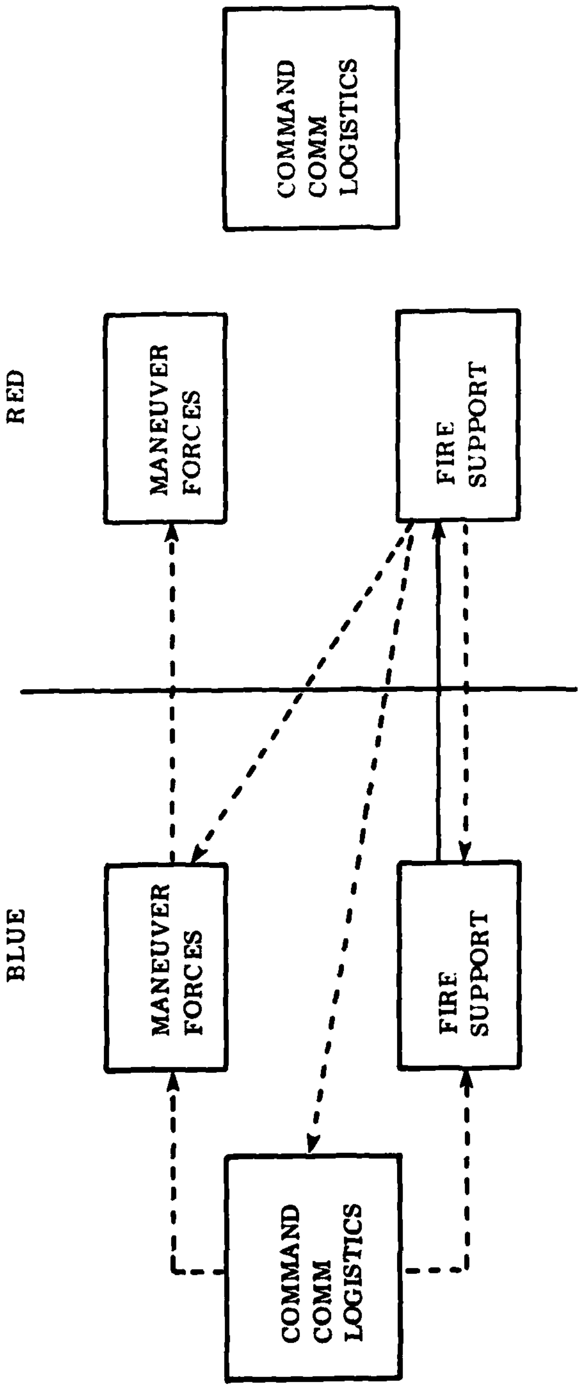
Further, counterbattery fire also has an effect in this situation which is discussed in the following subsection.

### 2.2.2.3 Counterbattery Fire

Figure 2.2.2.3 illustrates the influences of counterbattery fire on the overall battle. There are two overall effects of counterbattery fire which must be considered in the assessment of artillery effectiveness.

The first and most obvious effect is that successful friendly counterbattery fire can permanently or temporarily reduce the hostile fire support capability to suppress our maneuver forces. Conversely, hostile counterfire has the same effect on our fire support.

Secondly, counterbattery fire from either side is a net reduction in the amount of supporting fire which can be provided to the maneuver forces. To illustrate




REDUCE EFFECTIVENESS OF FIRE SUPPORT
- PERMANENTLY - KILL
- TEMPORARILY - SUPPRESS
  - DILUTE

COMBAT MOE'S

- NUMBERS OF WEAPONS & CREWS KILLED
- PERIOD OF SUPPRESSION
- RATIO OF RED COUNTERBATTERY TO SUPPORT FIRE

FIGURE 2.2.2.3

COUNTER BATTERY FIRE

this point, consider the potential impact of dispersed battery formations permitted by some of the technology initiatives discussed earlier. This tactic is usually thought of in terms of its ability to improve the survivability of friendly artillery weapons. However, another effect may be just as influential. If this tactic forces the Soviet artillery to fire counterbattery missions against individual U.S. artillery tubes, then the volume of Soviet counterbattery fire in order to achieve an equivalent suppressive effect has been multiplied by a factor of six. Depending upon the battle conditions this is a significant amount of fire power that is not delivered against U.S. maneuver forces. This ratio could be formulated as:

$$\text{RED FIRE RATIO} = \frac{\text{TOTAL ROUNDS - COUNTERBATTERY ROUNDS}}{\text{TOTAL ROUNDS}}$$

Most of the concepts of weighted casualties and suppression as measures of artillery effectiveness discussed previously for fire against the maneuver forces can be applied to the counterbattery fire situation. Further, the ratio of Soviet counterbattery to maneuver forces support fire may be a very sensitive measure of effectiveness to the tactics and technology of dispersal, shoot and scoot, etc.

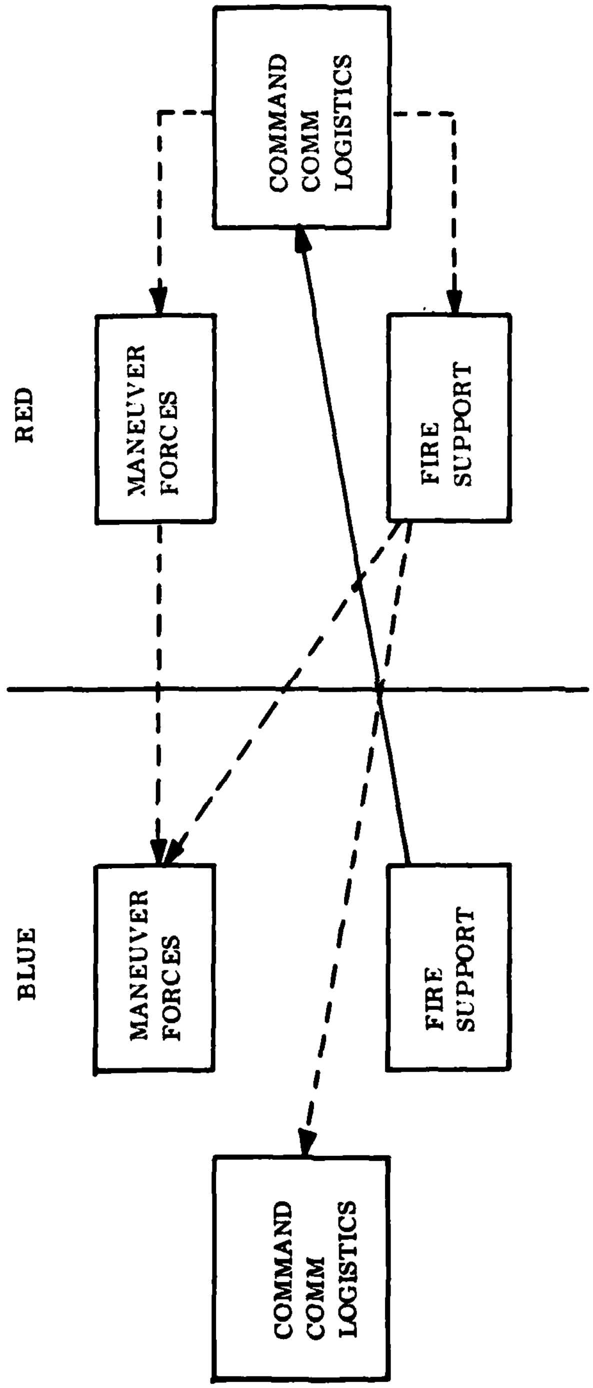
#### 2.2.2.4 Interdiction

The previous discussions of effectiveness of fire support against maneuver forces and opposition fire support have stressed immediacy of fire at the point of breakthrough as a major factor in determining combat effectiveness. The potential for fire support directed against enemy command communication and logistic facilities (interdiction) illustrated in Figure 2.2.2.4 works through a much longer time constant and it is questionable whether the concept of suppression has any impact in this area. The effect on the relative success or failure of the opposing maneuver forces are indirect and probably not quantifiable to anyone's satisfaction. Therefore, the number of casualties achieved is probably the only reasonable measure of combat effectiveness.

Further, in the area of interdiction the relative utility of artillery fire support vice the other elements of the combined arms team, rockets and air support, must be considered. This level of trade-off could only be achieved in a combat model of a scale sufficient to encompass all of these fire support elements as well as the relative logistic impact of their employment in interdiction.

### 2.2.3 Battle Model Requirements and Candidates

From the previous discussion of the measures of effectiveness which must be applied to the artillery mission within the overall combat team, the characteristics




INTERDICT
- COMMAND, COMM, LOGISTICS

COMBAT MOE'S
- NUMBER OF KILLS

FIGURE 2.2.2.4
INTERDICTION

desirable in an "ideal" battle model are apparent. The first and most evident characteristic is that the model must be fully two sided. The effects of suppression and the total effect of counterbattery fire demand the interaction of two opposing maneuver and fire support elements at a minimum. At a minimum, this ideal battle model should represent the two opposing maneuver forces at least to the extent of locating their geographical positions, and identifying the point or points of intended breakthrough of the side on the offensive.

Whether or not the model need incorporate the actual engagement of the two maneuver forces through a ground force combat model is debatable. From an artillery point of view, the measures of effectiveness suggested above can be determined with a "static" representation of the maneuver elements. Developing a maneuver force model to the point where a successful offensive side could exploit a breakthrough and move the FEBA would be highly complex. Further, such a battle model would require the accurate representation of all combined arms forces. This implies that the model should be an aggregated fire power score type or analytical (Lanchester equations) type. This level of complexity seems unwarranted since it duplicates the capability of existing division/corps/theatre combined arms models. The most useful battle model, from an artillery viewpoint, would assume a combined arms battle scenario as an input and measure the effectiveness parameters outlined earlier. Referring again to Figure 2.1.4, such an artillery battle model would effectively interface with a combined arms battle model. On the other hand, the ideal model must be both time extensive and area extensive.

The model must be time extensive so that the effect of logistic constraints, realistic ammunition resupply, reliability and maintainability, etc. can be brought to bear as realistic constraints on the measures of effectiveness.

The ideal model should be sufficiently area extensive to realistically account for the effects of artillery range, positioning relative to the FEBA and include the effects of reinforcing fire capability up to the corps level. Further, since it includes the deployment of the opposing maneuver forces the ideal model should incorporate the primary target acquisition sensors on each side in a realistic geometric model of their range and coverage capabilities. This aspect is particularly important from the point of view of counterbattery missions.

Finally, the ideal model should be easily adaptable to investigating some of the tactical alternatives made possible by advanced technology applications to the howitzer. These would include, at a minimum, shoot and scoot tactics and dispersed battery formations.

In surveying potential battle models to interface with the TCM, Veda surveyed the characteristics of existing versions of the AFSM model as well as all alternative larger scale models. As a result of this survey our recommendation to ARRADCOM is to interface the TCM with the new Fort Sill version of AFSM.

The existing versions of AFSM include, the old Fort Sill AFSM currently operational at ARRADCOM, the AMSAA version of AFSM and the TRASANA version of AFSM. The latter two AFSM versions incorporate improvements in such factors as red counterbattery capabilities and target acquisition. However, all three of these currently operational AFSM alternatives are essentially one-sided models. While various versions may include more or less sophisticated red counterbattery logic, none provides the capability for a relative assessment of the fire support effect on the opposing maneuver forces.

The alternative battle models which could provide such a measure include the AMSWAG at AMSAA, the DIVWAG at CDRO, VECTOR at DCA and DYNTACS at CACDA. All of these alternatives are two sided battle models ranging in scope from platoon to battalion to division to corps to theater level. All, however, are better candidates for a combined arms model.

The most promising battle model with which to interface the TCM appears to be one currently in development at Fort Sill termed the New Fort Sill AFSM. In terms of its algorithm characteristics, the New Fort Sill AFSM is in many ways similar to the existing AFSM versions. In particular, the TACFIRE target assignment logic, the target queing and the target effects, as far as assessing total casualties, are all very similar to earlier AFSM versions. However, several major improvements in the model directly address the "ideal" characteristics sighted earlier in this section. First, and probably most important, the New Fort Sill AFSM is intended to be a fully two-sided artillery effectiveness model. Those routines which deal with target acquisition, assignment, battery operations and target effects will be common to both the red and blue force. Each side, however, will access a different initialization data base reflecting the numbers, weapon types and deployment and a different performance data base reflecting system performance characteristic. Secondly, the New Fort Sill AFSM will include a representation of the opposing maneuver forces.

While this portion of the model is still in the very early stages of development, it was learned that the developers plan to go even somewhat further in representing the maneuver forces than we had suggested in the earlier discussion of this subject. That is, they plan not only to describe and deploy the opposing maneuver elements but also will attempt to model their relative combat success or failure as influenced by the relative capability of their fire support elements. One procedure

under consideration to achieve this capability is to implement a set of Lanchester equations with attrition on either side constituting a major parameter.

Additionally, the New Fort Sill AFSM will incorporate two sided target acquisition capabilities and ammunition resupply constraints which are essential in a valid two-sided battle model. The structured programming approach taken in implementing the model will allow relatively easy expansion to include critical details of the combat situation in the future. For example, the current model does not provide for electronic countermeasure effects on the artillery communications nets. However, the communications functions are isolated in specific subroutines which can be expanded with a minimum of reprogramming to implement any level of detail in a jamming effects model which is determined to be critical in the future.

While the New Fort Sill AFSM is a significant expansion in terms of model scope over earlier versions, the structured programming approach and data base design as well as the application of absolute addressing techniques apparently will result in a more efficient and faster model than current versions. The absolute addressing scheme will limit the hosting capability to CDC equipment, but this constraint will not limit its implementation at ARRADCOM.

At present, the New Fort Sill AFSM is completing the first phase of development at Fort Sill and currently is operational with essentially the same capabilities as the current one sided AFSM versions. Initial capability in a two-sided model is planned to be demonstrated early in calendar year 1980. This initial capability will not include maneuver forces or the ground war model. Manpower limitations at Fort Sill for continued development may delay this additional capability for as much as a year but even that long a delay may still be acceptable in terms of interfacing with a developmental TCM.

In summary, the design objectives for the New Fort Sill AFSM fit very closely with the "ideal" characteristics for a battle model sighted above. The fact that it is in a developmental status particularly as regards the two-sided characteristics and maneuver force representations may, in fact, be an advantage since greater flexibility exists in establishing the interface details between the TCM and the New Fort Sill AFSM. Finally, the structured programming approach applied in the simulation development should allow future growth in the model in those areas determined in the future to be most critical to howitzer technology assessment.

### 2.2.4 Effectiveness Summary

The foregoing extended discussion of artillery effectiveness measures and methodology is essential to establishing the context within which a TCM must perform.

In summary, the conclusions of this are:

- The military utility of artillery is significantly greater than its ability to create casualties.
- Absolute measures of suppression or force multipliers are probably invalid but relative measures are feasible and useful.
- Combined casualty and relative suppression measures which are weighted by the tactical precepts of FM 100-5 will be significantly more sensitive measures than unweighted casualties alone.
- Estimation of these weighted, relative measures requires a two-sided battle model.

In terms of their impact on TCM requirements, these conclusions imply that some specific effects must be comprehensively modelled within the TCM. These effects are discussed in the following subsection.

## 2.3 IMPORTANT EFFECTS TO BE MODELLED

Figure 2.3 categorizes the inputs to and outputs from the TCM. Although numerous individual outputs to the AFSM are required, these can be grouped into three major areas: weapon delivery characteristics, response and throughput. The weapon delivery characteristics refer to the spatial distribution of projectile deliveries relative to true target location. For area targets these characteristics include bias and random terms. For point targets, using CLGP, the characteristics include the probability of successful terminal acquisition.

The response characteristics refer to the temporal distribution of projectile deliveries relative to target life. Referring to the discussion of effectiveness measures in the previous subsection, the period of target life must include the factor of criticality to maneuver force engagement.

The throughput characteristics refer to the artillery battery's ability to process target assignments and ammunition over an extended period of battle time. These measures include such factors as: fire missions per hour; number of simultaneous fire missions; and number of rounds per hour. A number of other TCM outputs should be made available for "local" evaluation, but these three categories constitute the major outputs to AFSM.

**INPUTS**

- MEASURES OF DESIGN
- BATTLE ENVIRONMENT
  - TARGETS
  - COUNTERBATTERY
  - ECM
- PHYSICAL ENVIRONMENT
  - TERRAIN
  - WEATHER

**EFFECTS**

- TACTICS
- MANPOWER & MATERIEL READINESS
- HUMAN & MACHINE ERRORS
- AMMUNITION HANDLING
- COMMUNICATIONS
- MOBILITY
- SURVIVABILITY

**OUTPUTS**

- WEAPON DELIVERY CHARACTERISTICS
  - AREA TARGETS
  - POINT TARGETS
- RESPONSE
  - FIRE MISSIONS
  - MOVE ORDERS
- THROUGHPUT

FIGURE 2.3

IMPORTANT TCM EFFECTS

The inputs to the TCM can be categorized in three major areas as shown in Figure 2.3. The measures of design (MOD) are those subsystem and technology performance characteristics which describe the ability to perform each of the battery functions. The battle environment factors constitute the major inputs to the TCM from the AFSM. These include such factors as: targets and critical life; move orders; counterbattery sensors and fire response; and electronic countermeasures environment.

The physical environment factors include such inputs as terrain and weather. Typically, these factors may not be explicitly modelled in AFSM. However, they will be explicitly modelled in the TCM and since they can influence the TCM outputs, constitute an implicit interface between the two models.

There are seven major effects which must be accounted for by the TCM. These are highlighted in Figure 2.3 and are discussed in the following subsections.

### 2.3.1 Tactics

Several of the advanced technology initiatives are predicated on the assumption that future howitzer systems may be tactically employed in ways that are totally different from today's systems. As an example, on-board position location, azimuth reference and technical fire control may have some value in conventional battery deployments. However, this added capability naturally suggests the possibility of dispersed battery formations since each howitzer is capable of independent fire solutions given target data. This tactic has the potential to increase survivability in a heavy counterbattery environment. Conversely, the tactic makes the functions of communication, ammunition distribution and reconstitution more difficult.

In evaluating the potential of advanced technology/tactics combinations the issue is whether the advantages outweigh the disadvantages in a realistic battle environment. Further, the TCM must provide ARRADCOM visibility into which "undesirable side effects" are most limiting to system performance. With this information the most appropriate combinations of technology/tactics can be identified.

It is not feasible to design a TCM with sufficient flexibility to model any conceivable operational tactic. Therefore, it is important to define, prior to development, those primary tactical concepts of greatest interest. Two characteristics of any tactic are the deployment of battery assets (primarily howitzers) and the criteria for battery movement. Figure 2.3.1 illustrates these alternatives in matrix form and suggests those capabilities planned for the TCM.

| MOVE CRITERIA | DEPLOYMENT | |
|---|---|---|
| | CLOSE | DISPERSED |
| PLANNED-SIMULTANEOUS | X | |
| PLANNED-PSUEDO RANDOM | | X |
| IN RESPONSE TO COUNTERFIRE | X | X |

FIGURE 2.3.1
TACTICS MATRIX

### 2.3.2 Manpower & Material Readiness

Many of the howitzer technology initiatives are aimed toward the automation of currently manual functions. The ammunition handling, gun laying and weapon control technologies fall in this category. Their objective is to increase accuracy, reduce response time and maintain high firepower delivery rates in the presence of fatigue and attrition.

On the other hand, it is intuitively recognized by the development community that an over-automated howitzer system might suffer from low operational readiness and be less effective than current systems. From a system design viewpoint, the issue is which system functions have the greatest payoff when automated and which are marginal to counterproductive automation candidates.

The TCM must therefore be able to account for manpower limitations as well as material limitations. The following characteristics are essential:

- Each function of the howitzer and the artillery battery should be capable of a primary (automated or semi-automated) and secondary (manual) operating mode.
- The model should account for equipment failures and when such failure has occurred, revert to a secondary mode.
- The model should realistically limit the capability to perform any function by the manpower available.

With these capabilities the TCM will have the capability to evaluate, from response time and throughput viewpoints, the impact of automating any combination of functions.

### 2.3.3 Human and Machine Errors

The other aspect of automation, the reduction of errors in conducting a fire mission, must also be modelled by the TCM. The primary and secondary modes suggested above for manpower effects should also be applied to those functions where performance errors, as opposed to performance times, are critical.

It should also be accounted for that errors may combine differently depending on the technology being applied and the battery operating mode. For example, a battery in a distributed deployment firing from six independent firing data solutions

will have a different error distribution than a battery in a conventional deployment firing from a single solution. Further, any manual function should account for the probability of occasional gross error.

### 2.3.4 Ammunition Handling

The ability to handle and process ammunition is one of the two major constraints on the howitzer battery's throughput and long term average rate of fire. It is recognized that the realities of logistics limit the tons per day that can be supplied in most situations no matter what capability the battery has. Therefore, modelling the flow of ammunition up the logistic chain from the battery is not an essential for the TCM. These kinds of limits can be simply applied as a fixed tonnage rate input.

However, many of the technologies under consideration by ARRADCOM do influence the configuration of the projectile, propellant charges and how they are handled. Also, as noted in 2.3.1, the tactical operating mode of the battery can have a direct influence on the ability to transfer ammunition and the requirements for storage on the howitzer.

In order to assess the full impact of these technologies and tactics it is essential that the ability to model the handling and transfer of ammunition within the battery and with organic vehicles and handling equipment be provided. The effects accounted for should include both time, material (ammunition resupply vehicles) and manpower requirements.

### 2.3.5 Communications

While communications technology is not an ARRADCOM responsibility, the potential impact of communication capability on future howitzer alternatives is so great that it must be included in the TCM. The concepts of a dispersed battery formation and digital data transfer from a forward observer directly to a howitzer, among others, are critically dependent on the ability to establish and maintain communications.

As with automation, both primary and secondary communications modes should be modelled. The definition of the ECM environment from the AFSM should be in sufficient detail to allow the determination of when the primary mode is degraded or denied.

### 2.3.6 Mobility

The definition of mobility in this context includes more than just the average transit speed of the howitzer in moving from one firing point to the next. It includes all the functions which must be performed in order to prepare, move and emplace the gun in a new position, ready to fire.

These functions include, at a minimum, survey, gun laying, target registration, establishing communications and ammunition resupply. These functions become especially critical in the evaluation of alternative tactics and technologies such as on-board land navigation.

### 2.3.7 Survivability

Total survivability is composed of:

- The probability of being detected and located.
- The probability of being in the target area when counterbattery fire is received.
- The physical vulnerability of personnel and material when fire is received.

Each of these factors can be influenced by one or more technology initiatives or tactics.

The first factor implies the need in the TCM for a model of Soviet capability to detect and locate artillery fire and an AFSM input of the geographical location of specific sensors. This is essential to an adequate evaluation of peak rate of fire or dispersion to avoid accurate location. Also required from AFSM is an estimate of the number of batteries available for counterbattery fire and delays detection/location to recieved fire.

The final factor, physical vulnerability, impacts not only design of the howitzer and ammunition vehicles, but also several other performance factors. These factors include ammunition handling, communications and mobility.

## 2.4 APPLICATION OF MEASURES OF DESIGN (MOD)

It may at first appear that developing the input data which we call measures of design (MOD) may be the most difficult and expensive aspect of employing the TCM.

In some applications of the TCM model this may, in fact, be the case; but these applications are a small percentage of the TCM uses and the type of data required in these cases is the type of data which would be generated even if there were no TCM. To illustrate this point, some discussion of TCM uses is in order.

Any system engineering model such as the TCM has, in general, two modes of application. The first can be termed an "evaluation" mode and is characterized by the justification of a specific subsystem design application to a howitzer system design. As an example of this TCM application, consider the situation where ARRADCOM might be preparing for a major acquisition review for a new howitzer system. One major issue at this acquisition review might be, for example, the incorporation into the howitzer design of a new system of modular, consumable propellant charges which could be automatically assembled into the proper zone charge under computer control. The alternative would be conventional bag charges manually assembled. The former design option will require significantly higher Army investment costs but promises a higher peak rate of fire and reduced response time for CLGP missions. In this case, the TCM, in conjunction with AFSM, is being employed to provide the performance and effectiveness data to support a specific go/no-go decision on this issue. The acquisition review authority will require data which reflects not only the positive effects cited for the modular charge design, but also its potential negative effects which might include tube wear, or system reliability.

Clearly, in this case a considerable volume of engineering and test data would be required in order to properly evaluate the modular charge design in TCM. This data might include: a full reliability analysis of the automatic assembly and loading mechanism; extensive test firing data and wear measurements from a number of prototype tubes; and field test data on achieved firing rates and response times to moving targets obtained from a test bed system. This would represent a rather extensive, and expensive, data base. But this volume of data is not at all unusual in terms of the type of test and evaluation evidence which would normally have to be generated for a major acquisition review independent of any TCM application. The role of TCM in this case, after validation against the typically limited field test data base, is to extend that data base in terms of performance projections in more operational scenarios. These extensions would include such factors as personnel attrition, ammunition resupply and maintainability which may not have been present in the field test data base. Further, the existence of the TCM/AFSM simulations will have assisted in establishing the field test data requirements when they are introduced to the test planning process.

The second mode of TCM application can be termed the "what if" mode. This is the characteristic mode of application during the period of technology concept formulation, worth assessment and exploratory development. To illustrate this

situation, let us take a purely hypothetical example of an even more advanced propellant technology. Let us hypothesize that a new propellant becomes available with the characteristics of extremely high available specific energy, easily controllable by an electric charge. It is conceived by ARRADCOM that this propellant could be applied in a "all up round" in which the propellant is integral with the projectile. This concept, along with several others, is proposed as the basis for an exploratory development program.

At this point, it is typical that very little engineering data exists beyond some laboratory experiments with the propellant itself, a conceptual design of the projectile in which it might be employed and a schematic of external circuit for controlling propellant burning rate. Clearly, the engineering data base for evaluating this concept in the way that the previous example was evaluated is absent. However, the question in this case is not a commitment by the Army to the application of this concept to a fielded howitzer design. Rather the questions are: What is the priority of this technology for 6.2 funding vis-a-vis other technology candidates and; if this technology were to be funded, what performance characteristics must it demonstrate to be a candidate for future system application? The two questions are really interrelated. That is, the priority cannot be established without some conception of the potential design application and vice versa. In the absence of a significant engineering data base, how is TCM applied to this question and where do the measures of design come from?

The answer to this question is fundamental to the understanding of the capabilities and limitations of a system engineering simulation. No feasible system engineering simulation can possibly substitute for the engineering judgment of the developer. It would be a literal impossibility for a TCM model to accept the type of available engineering data in this example and from it produce howitzer battery performance measures. By analogy, there are aircraft design synthesis models which will accept materiels characteristics as an input and synthesize structural designs against mission performance requirements. However, this type of program operates within very defined boundaries of design concepts and employs well proven materials application criteria. A system engineering model such as the TCM will not synthesize designs for the user.

What a TCM will do, however, is allow the user to project to the system performance level the impact of design alternatives and varying levels of success in achieving technology performance goals. Let us return to our example to illustrate. The TCM should allow the user, in iterative steps, to define the potential application of this hypothetical propellant technology:

1. Establish the performance impact of known, but isolated, technology characteristics.

2. Explore alternative design applications which may impact one or more system performance measures.

3. Establish thresholds and goals for unknown but critical technology characteristics.

Iterative use of TCM in this example is shown in Figure 2.4.

In the first case, the known characteristics of the propellant chemistry and burning characteristics could be initially examined through a combination of off-line interior and exterior ballistics simulations and the TCM. This would establish the maximum range potential of the technology and its impact on battery performance measures such as dispersion characteristics or sustained rate of fire in isolation from other potential design impacts. These performance deltas could even be input to AFSM to establish the trend of their impact on effectiveness.

If this step indicates positive potential, then the next step would examine possible design alternatives in applying this technology. In the hypothetical example, the alternatives might be an all up round with integral propellant and projectile vice separately packaged modular propellant. Since no hard engineering data exists for either of these alternatives at this point, engineering judgment must be applied. A data base probably exists for separately loaded propellants in those measures of design such as ammunition handling time. These values would be adjusted for the weight and volume characteristics of the hypothetical propellant. The alternative all up round concept would then be evaluated parametrically with respect to a measure of design such as ammunition handling time. Iterative operation of the TCM would establish the values of this design measure at which the all up round concept is equivalent or superior to the conventional design alternative. Engineering judgment must again be applied as to whether these design measures are low risk or high risk engineering efforts.

If one or the other of these design alternatives begins to emerge as having clearly superior performance and effectiveness potential, then thresholds and goals must be established for unknown but critical application characteristics of the design. In the hypothetical example, little or no data may be available on the tube wear impact of the hypothetical propellant. This type of characteristic can be parametrically examined against the battery performance characteristics established during the evolution of a preferred design alternative. For example, the peak rate of fire performance measure for the all up round concept may have been established initially using nominal burning temperature characteristics. These characteristics would then be exercised parametrically to determine those design values at which the negative impact of tube wear begins to errode the advances in peak rate of fire achieved

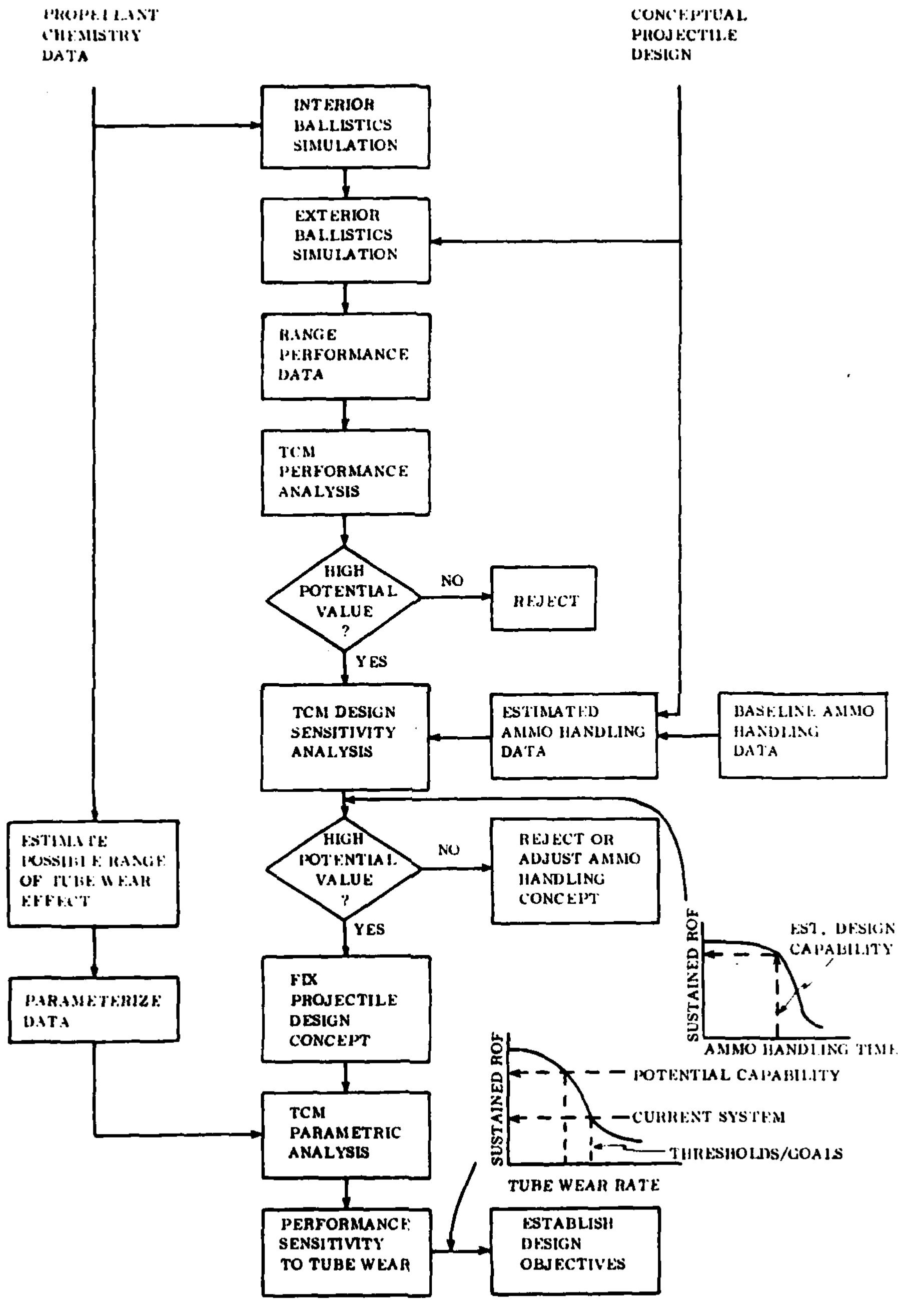



**FIGURE 2.4**

**"WHAT IF" MEASURES OF DESIGN**

by the all up round design concept. This type of iterative application of the TCM will bound those unknown characteristics which are critical to the conceptual design application and further establish quantitative boundaries for future evaluation.

In summary, the "what if" mode of operation of the TCM does not always require an extensive engineering data base. Rather, it allows ARRADCOM through iterative exercise, to evaluate the performance and effectiveness impact inherent to technology initiatives, explore alternative design application of these technologies and establish thresholds and goals to subsequently measure the achievement level of the resulting exploratory development programs. As these technology programs progress and provide an expanded base of engineering data this data, can be introduced into the TCM to provide a "real time" projection of performance and military effectiveness.

## 2.5 APPLICATIONS

### 2.5.1 General

As discussed in Section 2.4 there are basically two modes of operation of the TCM; the "evaluation" and the "what if" modes, both of which consist of performing a sensitivity analysis at either the battle level or battery (TCM) level. The difference between the two modes is the realism of the performance data used in the simulation and the realism of the data is determined by whether the overall analysis effort is being conducted from the top down (what-if), or from the bottom up (evaluation). The following sections will discuss in detail both of these approaches but prior to that some knowledge is required of the nature of the TCM as specified in Section 3.0 and a review is recommended at this time.

### 2.5.2 Top-Down Analysis

The top-down approach begins with a "what if" sensitivity analysis at either the battle or TCM level in an attempt to optimize a particular measure and results in passing down to the next lower level some specific performance or design measures to be improved.

For example a top-down analysis could be performed in response to the MENS requirement to reduce "labor intensity" in the field artillery. This analysis would begin at the TCM level and proceed as outlined in Table 2.5.2 and in fact these steps would be generalized to accommodate almost any top-down analysis. The individual steps are performed as follows:

TABLE 2.5.2

TOP-DOWN ANALYSIS EXAMPLE STEPS

1. Identify areas of labor intensity
2. Quantify advantages of system changes
3. Identify promising changes
4. Present requirements to technology areas for Design/ Feasibility study
5. Quantify Net Performance and Effectiveness gains
6. Perform support analysis of feasible changes
7. Prioritize changes by cost effectiveness

1. Identify Areas of Labor Intensity

This step would consist of running the TCM with special attention being given to reviewing Human Factors, Personnel and Manual Error statistics of a baseline system. The following are shortcomings which could be identified from the TCM run:

- Skill types with high fatigue levels.
- Instances where labor constrains system throughput.
- Tasks producing significant manual error.
- Manual tasks which are susceptible to Hostile and Environmental effects.

2. Quantify Advantages of System Changes

This entails running the TCM to determine the ideal performance gain to be achieved by automating the labor intensive tasks identified in step one. The ideal performance gain is the gain corresponding to a task which is automated to some reasonable function time with no error, failure or repair attributes included in the model. The performance gains would be measured against the same shortcomings which were identified in step one.

3. Identify Promising Changes

The identification involves reviewing the TCM output data to determine which changes produced significant ideal performance gains.

4. Present Requirements to Technology Areas for Design/Feasibility Study

Those changes which produced significant ideal performance gains would be given to the appropriate technology area along with the assumptions and results of the TCM run. The changes would be prioritized in order of highest gain for initial review. The review involves evaluating the technical feasibility of each change and providing conceptual design and performance parameters which are somewhat realistic as opposed to ideal.

5. Quantify Net Performance and Effectiveness Gains

Taking the performance parameters from step four, the TCM is run again to determine the Net Performance of each change. Net Performance reflects more realistic performance by including such factors as RAM and error parameters of the conceptual design. The TCM performance output is then maximized by considering alternative tactical methods of utilizing the new technology and the best combination of tactics and performance is taken to the AFSM battle model for effectiveness evaluation. At this point the TCM will provide the very important added capability to recommend changes in the AFSM simulation methodology which will tend to validate and sensitize the AFSM program to technology payoffs. This capability will develop as the actual design and use of the TCM proceed in that more understanding of the effects of technology changes and their degree of representation in AFSM will become apparent. An example of this can already be seen in the area of error simulation. The AFSM programs account for standard gun and projectile variations but do not take into account human errors which occur all too frequently at the firing unit. Table 2.5.2.1 is an extract of common mistakes and malpractices as listed in Appendix G to FM 6-50 and is an example of the kinds of human errors not included in the effectiveness currently predicted by the AFSM models. The TCM will collect both materiel and human errors and show their results upon target effectiveness. This will allow the advantages of technological improvements in reducing human error to be quantified and will provide a basis to recommend change in the AFSM programs.

6. Perform Support Analysis of Effective Changes

This step involves the cost estimation of development, production and life cycle support costs for the proposed changes. The estimates would be done using existing cost models and techniques with some data available from the TCM regarding failure and repair rates.

7. Prioritize Changes by Cost Effectiveness

At this point the effectiveness figures from the AFSM model and the cost estimate from step six provide a cost effectiveness ratio by which changes can be prioritized for development funding.

TABLE 2.5.2.1

COMMON MISTAKES AND MALPRACTICES PER FM 6-50

COMMON MISTAKES

Firing a wrong charge

Laying on the wrong aiming posts (especially at night)

Failure to zero the gunners aid

Transposition of numbers

Failure to level pitch and cross-level bubbles

Failure to compensate for backlash

MALPRACTICES

Improper ramming

Exceeding prescribed rates of fire

Leaving ammunition exposed to sunlight

Failure to clean projectiles

Attempting to boresight a weapon that is losing hydraulic pressure

Lifting a time-fuzed round with a hand on the fuze

Failure to use fuze wrench to tighten fuzes

AIMING CIRCLE MALPRACTICES

Not clearing the area of magnetic attraction

Failure to roughly orient the 0-3200 line

Reading red rather than black numbers

Making 100 Mil errors in reading or setting

### 2.5.3 Bottom-up Analysis

As mentioned previously a bottom-up analysis is an "evaluation" effort using more realistic performance data than the top-down approach. For a bottom-up analysis the TCM to AFSM input data should be the result of using actual howitzer performance data taken from system level tests or from a technical change which was actually tested or for which realistic design data exists.

A bottom-up analysis begins with the input to the TCM data base of the characteristics required by the model to evaluate the change. Table 2.5.3 is the TCM Data Base Requirements extracted from the specification and shows the type of data that will have to be known about a change prior to TCM evaluation. It is expected that each type of technology will be reflected in numerous moduels of the TCM and Table 2.5.3.1 is a cross reference between technology areas and modules and it shows that a given change will impact specific portions of the data base. The generation of the data base changes will require some off-line analysis to assess such things as interaction between functions and the resultant effect on personnel requirements, even if the change is already developed. It is believed that most of the data base information can easily be generated by existing engineering models and analysis methods with little or no change provided some consideration is given, during TCM design, to the format and methodology involved. A specific example of data base input is the requirement for environmental time factors as shown in Table 2.5.3.2. The table allows for all valid combinations of environmental status as defined below.

1 = Yes
0 = No

TEMPERATURE:
High, Medium and Low

PRECIPITATION:
Yes or No

FOG
Yes or No

NIGHT
Yes or No

The design engineer must determine a task or function time for each combination of conditions by reviewing test data or design requirements. The time required

TABLE 2.5.3

EXAMPLE DATA BASE REQUIREMENTS

ENVIRONMENTAL DATA
- Time factors for material
- Wear factors for material
- Time factors for personnel

HUMAN FACTORS DATA
- Workload index by task
- Complexity index by task

PERSONNEL DATA
- Personnel assignment
- Task skill level requirements
- Task manpower requirements

HOSTILE EFFECTS DATA
- Normal personnel locations and posture
- Secondary personnel locations and posture
- Material hardness index

RAM DATA
- Mean failure value and units of measure
- MTTR, repair echelon
- Skill and manpower requirements for organizational repairs

FUNCTION PERFORMANCE DATA
- Cycle times, manual and automatic
- Error data, mean value, variance
  hostile effects on mean or variance
  wear effects on mean or variance

AMMUNITION EFFECTIVENESS DATA
- Friendly and hostile JMEM type data

MOBILITY EQUIPMENT DATA
- Type and Quantity of vehicles
- Speed, range and capacity versus terrain

COMMUNICATIONS EQUIPMENT DATA
- Equipment assignment
- Range, transmission time/rate
- Operating frequencies

TABLE 2.5.3.1

TECHNOLOGY AREA TO TCM MODULE CROSS REFERENCE

| TCM MODULES \ TECHNOLOGY AREAS | PROPELLANTS | PROPELLANT PACKAGING | FUZE SETTING | FUZES | RECOIL MECHANISMS | TUBES | BREECHS | PROJECTILES | BORE EVACUATORS | PRIMING | MUZZEL BRAKES | LOADERS | GUN LAYING | COMMUNICATIONS | NAVIGATION | TECHNICAL FIRE CONTROL | AMMUNITION HANDLING | MOBILITY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MOBILITY | | | | | | | | | | | | | | | X | | | X |
| COMMUNICATIONS | | | | | | | | | | | | | | X | | | | |
| BATTERY HANDLER | | | | | | | | | | | | | | | | | | |
| $C^3$ | | | | | | | | | | | | | | | | | | |
| AMMUNITION RESUPPLY | X | X | | X | | | | X | | X | | | | | | | | |
| ERRORS | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| BATTERY AMMUNITION | X | X | | X | | | | X | | X | | | | | | | X | |
| FIRING BATTERY | | | | | | | | | | | | | X | | | | | |
| INDIVIDUAL GUN FUNCTIONS | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | X | |
| FIRE DIRECTION | | | | | | | | | | | | | | | | X | | |
| TARGET ACQUISITION | | | | | | | | X | | | | | | | | | | |
| PERSONNEL | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| HUMAN FACTORS | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| ENVIRONMENTAL EFFECTS | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| HOSTILE EFFECTS | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| RAM | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| TARGET EFFECTS | | | | X | | | | X | | | | | | | | | | |

TABLE 2.5.3.2

TABLE OF ENVIRONMENTAL FACTORS

| TEMP | | | PREC | FOG | NIGHT | ENVIRONMENTAL FACTOR |
|---|---|---|---|---|---|---|
| HI | MED | LO | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | |
| 1 | | | | | 1 | |
| 1 | | | | 1 | | |
| 1 | | | | 1 | 1 | |
| 1 | | | 1 | | | |
| 1 | | | 1 | | 1 | |
| 1 | | | 1 | 1 | | |
| 1 | | | 1 | 1 | 1 | |
| 0 | 1 | 0 | 0 | 0 | 0 | 1.0 |
| | 1 | | | | 1 | |
| | 1 | | | 1 | | |
| | 1 | | | 1 | 1 | |
| | 1 | | 1 | | | |
| | 1 | | 1 | | 1 | |
| | 1 | | 1 | 1 | | |
| | 1 | | 1 | 1 | 1 | |
| 0 | 0 | 1 | 0 | 0 | 0 | |
| | | 1 | | | 1 | |
| | | 1 | | 1 | | |
| | | 1 | | 1 | 1 | |
| | | 1 | 1 | | | |
| | | 1 | 1 | | 1 | |
| | | 1 | 1 | 1 | | |
| | | 1 | 1 | 1 | 1 | |

under the conditions of; medium temperature, clear weather and daylight is considered the normal time, with a factor of one, and all other times are normalized to that time value, the ratio of which provides the factor. This factor will then be taken into consideration during the simulation and will be reflected in the performance statistics output by the TCM.

# SECTION 3.0

# TCM SPECIFICATION

## 3.1 GENERAL

This specification defines the functional requirements for a computer simulation of an aritllery weapon and its surrounding environment. The simulation will be used to evaluate the effects of changes to components of a weapon, by providing output data which can be used to assess changes in system performance or which can be provided to battle level simulations as input data for analysis at the effectiveness level. The program will therefore provide the capability to translate basic engineering data, relative to weapon components, into system performance and, via a suitable battle model, system effectiveness. Further, the program shall provide for a local measure of effectiveness and account for resulting enemy counterattack in a manner which will be indicative of the results to be obtained at the battle level. In simulating the weapon performance the model shall incorporate the effects of the environment, wear and the resulting personnel and resupply demands. The objective of the simulation shall be to portray the advantages and disadvantages of technical changes as they would appear in a real tactical environment and to provide the capability to either evaluate these changes as a new design application for which test data can be obtained, or to play the "what if" game of searching for the optimal effectiveness payoff with assumed technical data.

The model defined herein has, what is presently considered, the ultimate TCM functional capability and can be designed in a modular fashion which will allow a near term capability with growth to the full model as desired in the future.

## 3.2 PROGRAMMING APPROACH

### 3.2.1 Overall Approach

The model will be designed for running on the ARRADCOM CDC 6000 computer system with the NOS/BE Level 499 Operating System and coded in CDC Level 4.8+498 FORTRAN. It will be an event oriented simulation using either random or deterministic functions to model entities as appropriate. For the sake of expediting steady-state analysis of the Howitzer system, the model shall be capable of operating in a non-random fashion using only mean values if random functions are included in the design. The initialization will be designed to minimize the input requirements of the operator and facilitate use of the model.

### 3.2.2 Inputs

The inputs required to run the model will fall into one of three categories, namely; Tactical Input, Administrative Input and Data Base Changes. An example of the information required to be input is shown in Table 3.2.2 and every attempt shall be made in the program design to minimize the input data requirements for the sake of making the model easy to use.

### 3.2.3 Outputs

There will be two types of outputs generated by the TCM; local effectiveness data and system performance data. The system performance output will include the parameters required to input the battle model and consist of data gathered from all of the functional modules of the program. The total number of statistics and their combinations which can be gathered from this model are potentially very large and some discretion is required in selecting the ones required for a particular analysis effort. An example of a nominal set of output data is shown in Table 3.2.3. The design of this model shall provide the outputs which will be essential as input to the battle model and provide for selections of output statistic combinations most likely to be needed for general performance and effectiveness studies. The model design will allow for the addition of data reduction routines should they be desired in the future.

### 3.2.4 Data Base Requirements

Initial data base setup will require the establishment of the unit configuration of personnel and equipment to include vehicles by type and quantity, communication equipment by type and vehicle assignment, personnel assignments by skill and quantity and the associated performance data and relevant factors such as those show in Table 3.2.4. After the data base has been established and analysis of technical or organizational changes is desired only those elements affected by the modification will be changes.

During the design of the model; the data base requirements will be fully defined as to exact content and format, and a system for generating the data will be prepared. Also a methodology will be developed by which the environment, human factors and personnel skill levels will affect both the time and accuracy of manual tasks and the time and wear rate of automatic functions. This methodology will utilize the environmental factors, human factor indices and task requirements shown in Table 3.2.4 to adjust the time and accuracy of a function relative to existing environmental conditions, personnel fatigue levels or as a result of primary, secondary or tertiary skill applications to a task. For example a task or function which requires five minutes to perform under nominal environmental conditions might require twice as long at low temperature and therefore an environmental time factor of two would be required in the data base. Table 3.2.4.1 is the set of environmental conditions for which factors will be required in the data base.

TABLE 3.2.2
TCM INPUTS

- TACTICAL INPUT

  Tactical Mode of Operation

  - Ammunition resupply policy
  - Battery movement policy
  - Communications net structure
  - Battery dispersion policy
  - Fire mission queueing policy

  Scenario Data

  - Target Data
    - Type, Size, Posture, Environment, Location, Duration, Priority/Worth
  - Ammunition Resupply Data
    - Available rounds/unit time
  - Environmental Data
    - Temperature, Precipitation, Fog, Night
    - By time of occurrance
  - Hostilities Data
    - Probabilities of Detection, Response Time, Type Response, Duration
  - $C^3$ Data
    - Move orders, Alerts, High Priority and TOT Fire Missions

  Scenario Data (Continued)

  - Terrain Data
    - Type, Percentage
  - Initial Locations
    - Grid Coordinates of Battery Elements

- ADMINISTRATIVE INPUT
  - Run Time
  - Output Data Selection
  - Mode Selection
    - Mean Value, Random

- DATA BASE CHANGES
  - Any changes to data elements of Table 3.2.4

# TABLE 3.2.3

## TCM OUTPUT DATA

### LOCAL EFFECTIVENESS

- TARGET EFFECTS
  - Total number of targets processed by type
  - Number and percent of targets killed by type
  - Target suppression factor to include time, area, degree
  - Maximum, average and minimum rounds expended by target type
- HOSTILE EFFECTS STATISTICS

  Counterfire:
  - Total number of hostile rounds fired by type
  - Total number of hostile counterfire attacks
  - Maximum duration of counterfire
  - Average duration of counterfire
  - Personnel losses due to counterfire by round type
  - Material losses due to counterfire by round type
  - Average rate of fire during counterfire

  Electronic Warfare:
  - Number of messages jammed by type
  - Number of jamming periods while battery firing
  - Number of jamming periods while battery moving
  - Total firing delay caused by jamming
- ENVIRONMENTAL STATISTICS
  - Maximum and average rates of fire by environmental condition
  - Maximum, minimum and average move times by environmental condition

### SYSTEM PERFORMANCE

- GUN/BATTERY STATISTICS
  - Percent of time firing
  - Percent of time moving
  - Percent of time failed
  - Maximum rate of fire
  - Average rate of fire
  - Total number of rounds fired by target type
  - Time statistics on each gun function
- AMMUNITION STATISTICS
  - Projectiles & Fuzes
    - Total number used by type
    - Maximum rate of use by type
    - Average rate of use by type
    - Number redistributed by type
  - Charges
    - Total propellants used
    - Number used by charge
    - Percentage of total by charge
- FIRE DIRECTION STATISTICS
  - Total number of targets prosecuted
  - Total number of targets lost
  - Breakdown of targets by range and type
- PERSONNEL STATISTICS
  - Total number by type at start
  - Total remaining by type at end
  - Percentage of time spent in primary skill by type
  - Percentage of time spent in secondary skill by type
  - Percentage of time spent in tertiary skill by type

### SYSTEM PERFORMANCE (Continued)

- ERROR STATISTICS

  For each gun and the whole battery
  - Maximum, minimum and average error by type
  - Maximum, minimum and average shot error
  - Maximum, minimum and average target location error
- MOBILITY STATISTICS

  For each vehicle
  - Total moving time
  - Total down time
  - Total stationary time
  - Maximum move distance
  - Average move distance
  - Shortest move distance
  - Maximum move time
  - Average move time
  - Shortest move time
- COMMUNICATIONS STATISTICS

  For each link in the net
  - Total use time, total down time, total idle time
  - Maximum message length
  - Average message length
  - Minimum message length
  - Amount of time jammed
- RAM STATISTICS
  - Gun system average failure and repair times
  - Total number of failures by failure type
  - Maximum number of failures at one time
  - Average number of failures at one time
- HUMAN FACTORS STATISTICS
  - Total work performed by skill type
  - Maximum and average workload by skill type

TABLE 3.2.4

EXAMPLE DATA BASE REQUIREMENTS

| | |
|---|---|
| **ENVIRONMENTAL DATA**<br>• Time factors for material<br>• Wear factors for material<br>• Time factors for personnel | **FUNCTION PERFORMANCE DATA**<br>• Cycle times, manual and automatic<br>• Error data, mean value, variance<br>hostile effects on mean or variance<br>wear effects on mean or variance |
| **HUMAN FACTORS DATA**<br>• Workload index by task<br>• Complexity index by task | **AMMUNITION EFFECTIVENESS DATA**<br>• Friendly and hostile JMEM type data<br>**MOBILITY EQUIPMENT DATA**<br>• Type and Quantity of vehicles<br>• Speed, range and capacity versus terrain |
| **PERSONNEL DATA**<br>• Personnel assignment<br>• Task skill level requirements<br>• Task manpower requirements | **COMMUNICATIONS EQUIPMENT DATA**<br>• Equipment assignment<br>• Range, transmission time/rate<br>• Operating frequencies |
| **HOSTILE EFFECTS DATA**<br>• Normal personnel locations and posture<br>• Secondary personnel locations and posture<br>• Material hardness index | |
| **RAM DATA**<br>• Mean failure value and units of measure<br>• MTTR, repair echelon<br>• Skill and manpower requirements for organizational repairs | |

TABLE 3.2.4.1

TABLE OF ENVIRONMENTAL FACTORS

| TEMP | | | PREC | FOG | NIGHT | ENVIRONMENTAL FACTOR |
|---|---|---|---|---|---|---|
| HI | MED | LO | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | |
| 1 | | | | | 1 | |
| 1 | | | | 1 | | |
| 1 | | | | 1 | 1 | |
| 1 | | | 1 | | | |
| 1 | | | 1 | | 1 | |
| 1 | | | 1 | 1 | | |
| 1 | | | 1 | 1 | 1 | |
| 0 | 1 | 0 | 0 | 0 | 0 | 1.0 |
| | 1 | | | | 1 | |
| | 1 | | | 1 | | |
| | 1 | | | 1 | 1 | |
| | 1 | | 1 | | | |
| | 1 | | 1 | | 1 | |
| | 1 | | 1 | 1 | | |
| | 1 | | 1 | 1 | 1 | |
| 0 | 0 | 1 | 0 | 0 | 0 | |
| | | 1 | | | 1 | |
| | | 1 | | 1 | | |
| | | 1 | | 1 | 1 | |
| | | 1 | 1 | | | |
| | | 1 | 1 | | 1 | |
| | | 1 | 1 | 1 | | |
| | | 1 | 1 | 1 | 1 | |

The table allows for all valid combinations of enfironmental states as defined below.

TEMPERATURE:

High, medium and low

PERCIPITATION:

Yes or No

Fog

Yes or No

Night

Yes or No

1 = YES

0 = NO

The design engineer must determine a task or function time for each combination of conditions by reviewing test data or design requirements. The time required under the conditions of; medium temperature, clear weather and daylight is considered the normal time, with a factor of one, and all other times are normalized to that time value, the ratio of which provides the factor. Similar factors will be defined to relate personnel and human factors to tasks and functions.

## 3.3 MODEL REQUIREMENTS

### 3.3.1 Functional Characteristics

In order to provide realism; the model shall simulate the performance of a weapon as it is used in an artillery battery, and the battery shall be simulated as it would be used in a battle scenario. The top level structure of the model will therefore incorporate those elements shown in Figure 3.3.1. The Battery module (see Figure 3.3.1.1) will model the functions of an artillery battery, and include in most detail the operation of the gun itself. The Hostile Effects, Target Acquisition and $C^3$ modules will be the primary sources of tactical realism since they shall operate on tactical data provided by the battle level model. The Target Effects module shall be identical to that used by the battle model in order to provide an indication, at the local level, of what effectiveness results will be seen at the battle level. The Environmental Effects, RAM and Human Factors modules shall introduce the real-world effects of weather, wear and human resources into the simultaion.

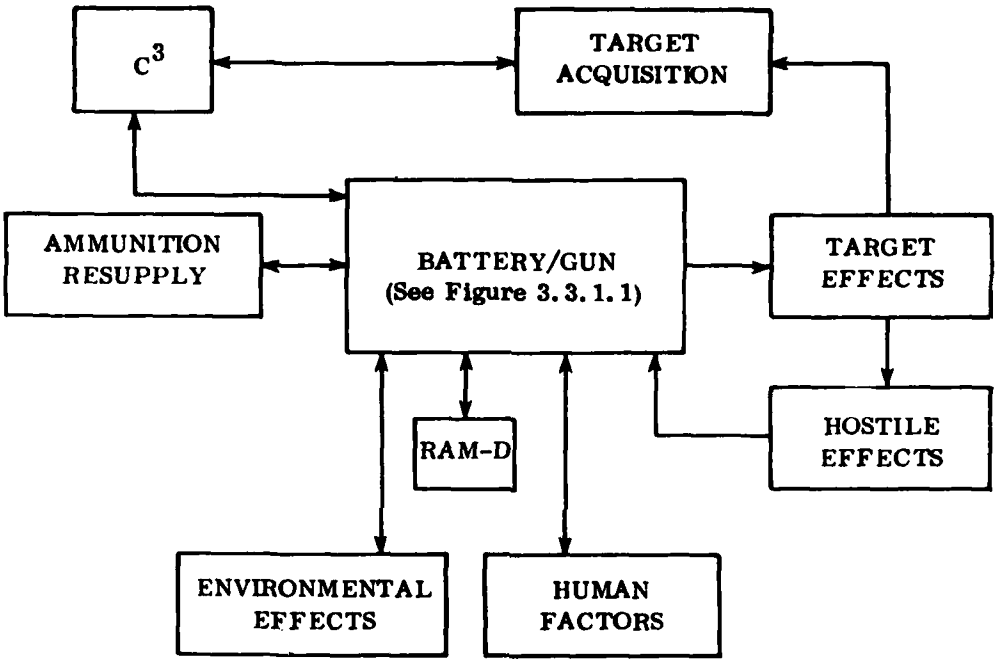



FIGURE 3.3.1

TECHNOLOGY MODEL TOP LEVEL STRUCTURE

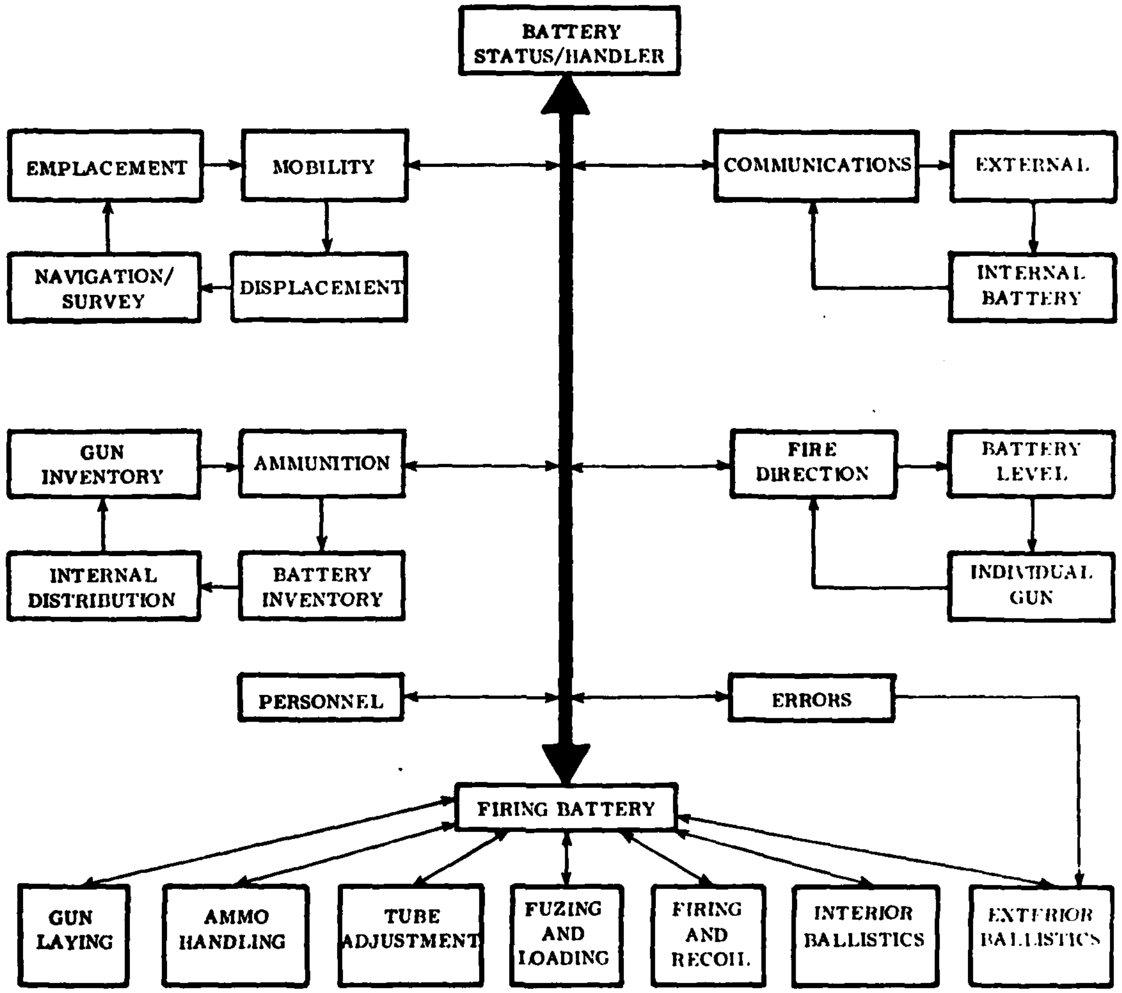



FIGURE 3.3.1.1

BATTERY MODULE INTERNAL STRUCTURE

3.3.2 Interfaces

The TCM simulation will be designed to run in a stand-alone mode having no real-time interfaces with other simulations. It will interface with other simulations, mathematical models and sources of technical data as shown in Figure 3.3.2 in an off-line information exchange manner.

3.3.2.1 AFSM Interfaces

3.3.2.1.1 TCM to AFSM

Both the AMSAA and New Fort Sill versions of the Artillery Force Simulation Model (AFSM) use technical performance and tactical employment characteristics of existing artillery units (Batteries) to predict division level effectiveness. The technical performance data relative to a fire unit is included in the AFSM input data, data-base and ingrained in the program logic. The tactical operating policy and configuration of the unit is mostly reflected in the program logic and somewhat in the input data. It is therefore necessary that the TCM input to AFSM contain not only the measures of technical performance achieved by a new design but also the tactical policies and support system performance data which was used with or resulted from the evaluation. Table 3.3.2.1.1 shows the types of TCM to AFSM inputs and they are divided into three categories; Normal AFSM Program Input, Other Performance Data and Tactical Data. These three categories will be provided to the AFSM user so that he can consider not only the weapon performance resulting from a technical change but the associated changes in support functions and method of employment which may require alteration of his program assumptions and logic.

3.3.2.1.2 AFSM to TCM

The battle models will provide the TCM that information necessary to interface the TCM with the tactical scenario as seen at the battery level. Which ever artillery unit in the battle is chosen Direct Support, General Support or Reinforcing, the tactical information relative to that unit will be required as input to the TCM. The battle data as shown in Table 3.3.2.1.2 will be taken as input to the TCM and used to determine the performance of a new or changed weapon in a particular scenario.

3.3.2.2 Supporting Models

The TCM will require information from other models or sources of technical data which will provide performance parameters for use in modelling target effects, communications, mobility and personnel functions within the TCM. Table 3.3.2.2 shows type type of data required for each category which can be derived from; simulations, mathematical models, graphic models, manuals or any valid source of the required data.

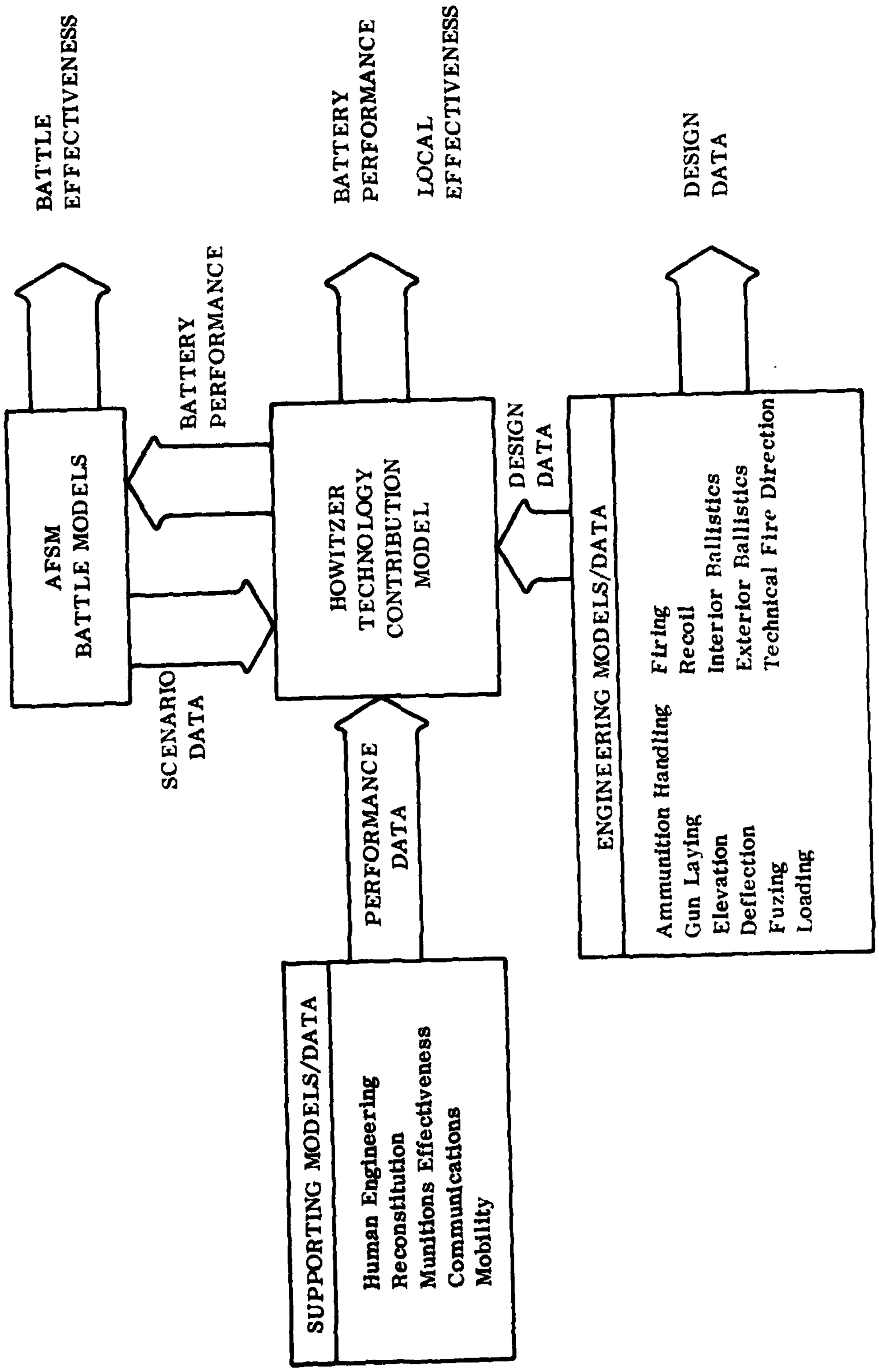



FIGURE 3.3.2
TCM INTERFACES

TABLE 3.3.2.1.1

TCM TO AFSM INPUT

| NORMAL AFSM PROGRAM INPUT | |
|---|---|
| Number of tubes in a fire unit | Weight |
| Sustained rate of fire | Cost |
| Burst rate of fire | Reliability |
| Maximum range | Basic load |
| Number of volleys per mission | Range vs. EFC data |
| Time required between missions | Round errors (CPE) |
| Basic battery ammunition load | System errors (CPE) |
| Battery resupply rate | Round lethal zones |
| Minimum tubes per battery | |
| RAM data | |
| **OTHER PERFORMANCE DATA** | |
| FDC statistics | Environmental statistics |
| Personnel statistics | Error statistics |
| Mobility statistics | Local effectiveness statistics |
| Communications statistics | Hostile effects statistics |
| **TACTICAL DATA** | |
| Ammunition resupply policy | Battery dispersion policy |
| Battery movement policy | Fire mission queueing policy |
| Communications net structure | |

TABLE 3.3.2.1.2

AFSM TO TCM INPUT

| |
|---|
| • Target Data<br>- Type, Size, Posture, Environment, Location Duration, Priority/Worth |
| • Ammunition Resupply Data<br>- Available rounds/unit time |
| • Environmental Data<br>- Temperature, Precipitation, Fog, Night<br>- By time of occurrance |
| • Hostilities Data<br>- Probabilities of Detection, Response Time, Type Response, Duration |
| • $C^3$ Data<br>- Move orders, Alerts, High Priority and TOT Fire Missions |
| • Terrain Data<br>- Type, Percentage |
| • Initial Locations<br>- Grid Coordinates of Battery Elements |

TABLE 3.3.2.2

SUPPORTING MODELS TO TCM INPUT

| TARGET EFFECTS |
| --- |
| • Joint Munitions Effectiveness Type Data<br>Friendly, Hostile |
| **COMMUNICATIONS AND MOBILITY** |
| • Performance<br>• RAM<br>• Environmental Factors<br>• Material Hardness Index |
| **PERSONNEL** |
| • Human Factors<br>workload and complexity index<br>• Task Requirements<br>skill, manpower levels<br>• Hostilities Data<br>Primary and secondary location and posture |

3.3.2.3 Engineering Models

The engineering model block of Figure 3.3.2 listed the set of firing battery functions which will be simulated within TCM at the design level. For each of these functions (see Table 3.3.2.3) the engineering data base will require the cycle times (manual and automatic) and error data as related to variable input data for that function. The engineering models will also provide some estimated or actual RAM data and environmental and material hardness factors.

3.3.3 Functional Requirements

The functional breakdown of Figure 3.3.3 shows the seventeen modules required to comprise the simulation. They are a combination of functions which portray the internal workings of an artillery unit and the external factors which analytically place it in the real world, together this set of modlues will provide the capability to analyze technical changes as they would affect real world system performance. The functional requirements and interfaces of each module are defined in the following sections.

3.3.3.1 Firing Battery Module

This module will simulate the Firing Battery portion of the artillery unit which performs the function of coordinating and firing the weapons. It will account for the time and resource requirements of the Firing Battery Headquarters section, which performs the coordinating and laying of the guns and add to this the time and errors generated by each individual gun function defined in paragraph 3.3.3.2. This module will contain the logic which defines the sequence of events which has to occur for a shot to be fired and will execute this series using the individual gun functions to provide the time and accuracy components which combine to form the time and accuracy for the whole shot. It will also contain the logic for redundant sequences which can be used in case of a mechanism failure. Of primary importance is the fact that the gun functions will be discrete enough to allow the originator of a new design or concept to reasonably determine the data base information relative to the function.

3.3.3.1.1 Inputs and Outputs

The Firing Battery Module will require inputs from and outputs to other modules of the simulation as shown in Figure 3.3.3.1. This set of interfaces will allow the Firing Battery modules to perform its functions of controlling the gun functions, accounting for resource requirements for the firing battery headquarters section and providing the appropriate errors and ballistics data.

TABLE 3.3.2.3

ENGINEERING MODELS TO TCM INPUT

| FIRING BATTERY FUNCTIONS | |
|---|---|
| • Ammunition Handling | • Firing |
| • Gun Laying | • Recoil |
| • Elevation | • Interior Ballistics |
| • Deflection | • Exterior Ballistics |
| • Loading | • Technical Fire Direction |

| REQUIRED DESIGN DATA |
|---|
| • Performance Data Time, Errors |
| • RAM Data |
| • Environmental Factors |
| • Material Hardness Factors |

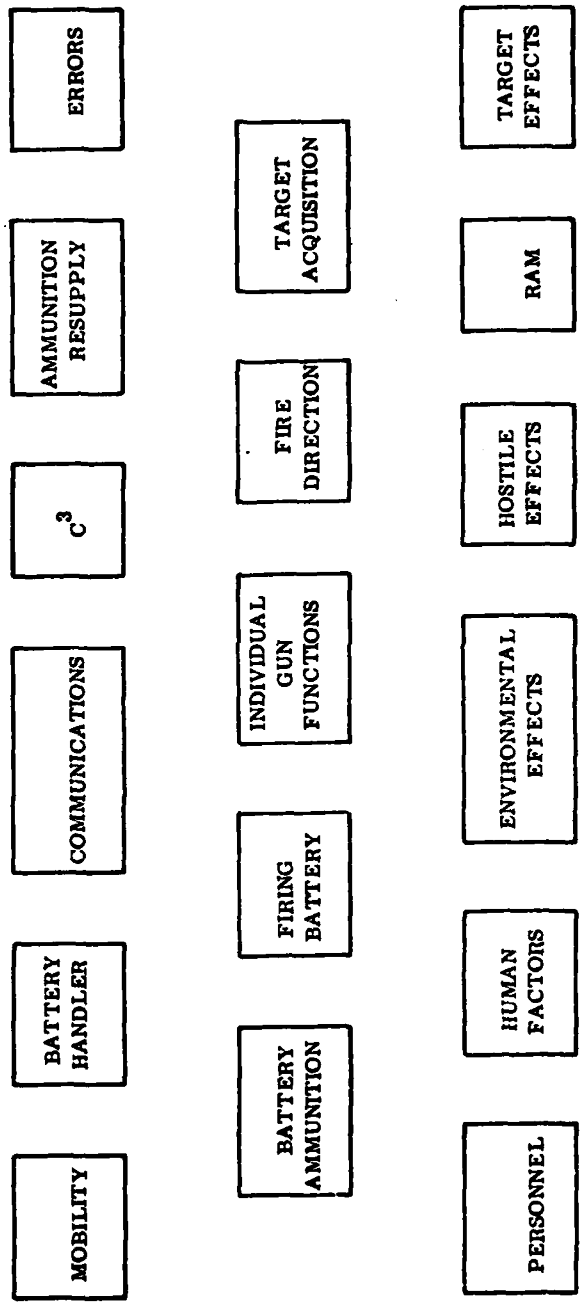



FIGURE 3.3.3

TECHNOLOGY CONTRIBUTION MODEL FUNCTIONAL BREAKDOWN

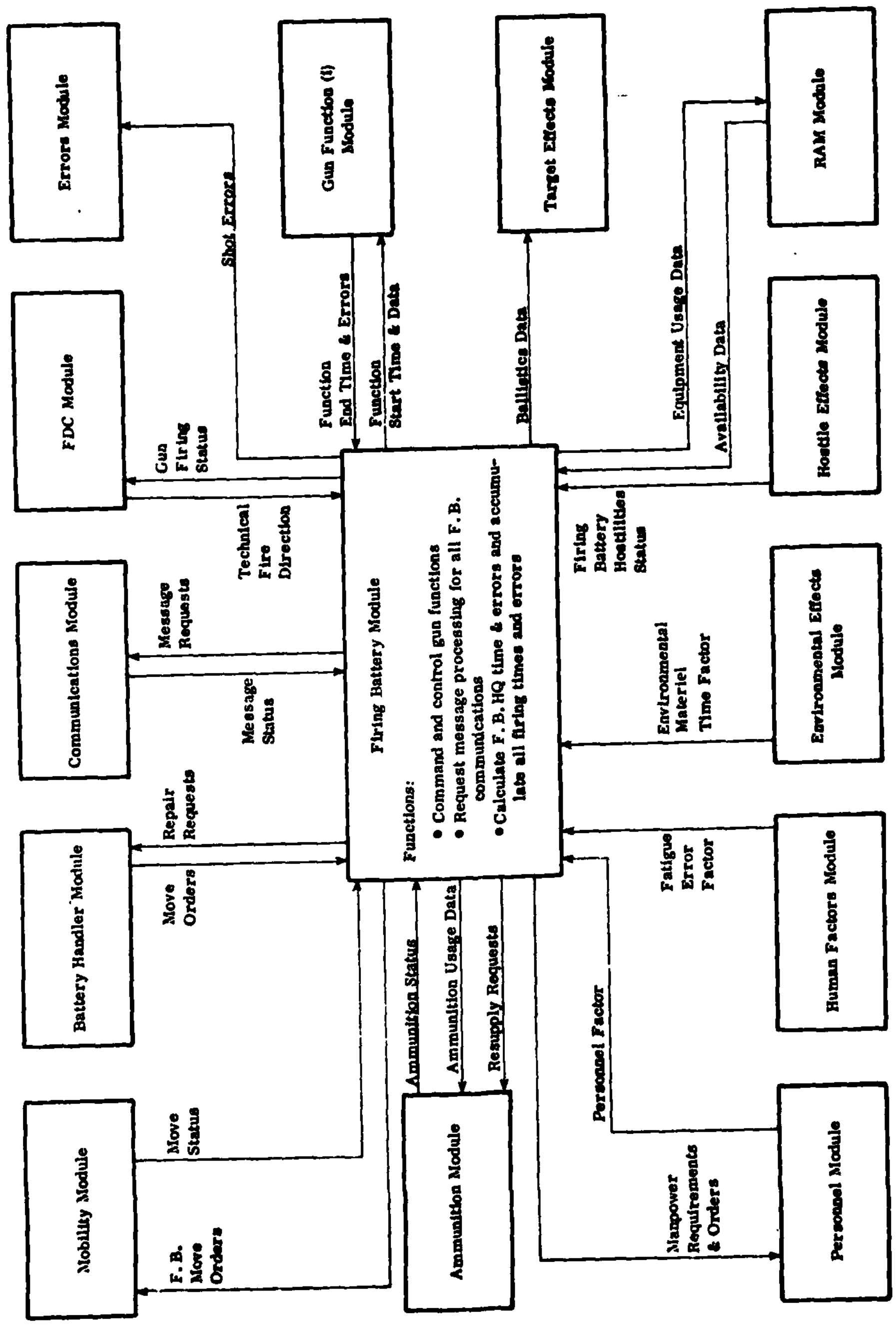



FIGURE 3.3.3.1

FIRING BATTERY MODULE FUNCTIONAL INTERFACE DIAGRAM

### 3.3.3.2 Individual Gun Functions

This module will be subordinate to the Firing Battery Module and will be a generalized routine which will calculate the time and accuracy of each individual function of a gun or Howitzer for a given set of input parameters. The time calculation will include both automatic and manual time requirements in a joint function as shown below.

Function Time = F (automatic time, manual time)

where

Automatic Time = F (nominal time, personnel factor)
Manual Time = F (nominal time, personnel factor)

This will allow the effects of personnel and environment to bias the function time. The calculation of function errors will likewise be a joint calculation involving both automatic and manual contributions as:

Function Errors = F (automatic errors, manual errors)

where

Automatic Errors = F (design tolerances, material error factor)
Manual Errors = F (nominal error, fatigue error)

This allows the effects of wear, hostilities, environment and personnel to be included in the calculations. This function will also calculate the values for a redundant or back-up mechanism as well as a primary one. The decision as to which mode will be used is made by the Firing Battery module.

#### 3.3.3.2.1 Inputs and Outputs

The individual gun functions will interface with the other modules of the simulation as shown in Figure 3.3.3.2. This set of interfaces allows the function to draw upon the data required to simulate a specific task, and output the results. This function will receive input and generate output data for the set of individual functions shown in Figure 3.3.3.2.1.

### 3.3.3.3 Fire Direction Module

The purpose of the Fire Direction Module is to provide the simulation the ability to reflect the time and resources involved in using target information to determine firing data for the guns. At present this is referred to as "technical fire direction" as opposed to "tactical fire direction" which is normally the function performed by a Battalion FDC, of allocating targets to Batteries, using some tactical reasoning. No attempt will presently be made to perform tactical fire direction at the battery level but impending

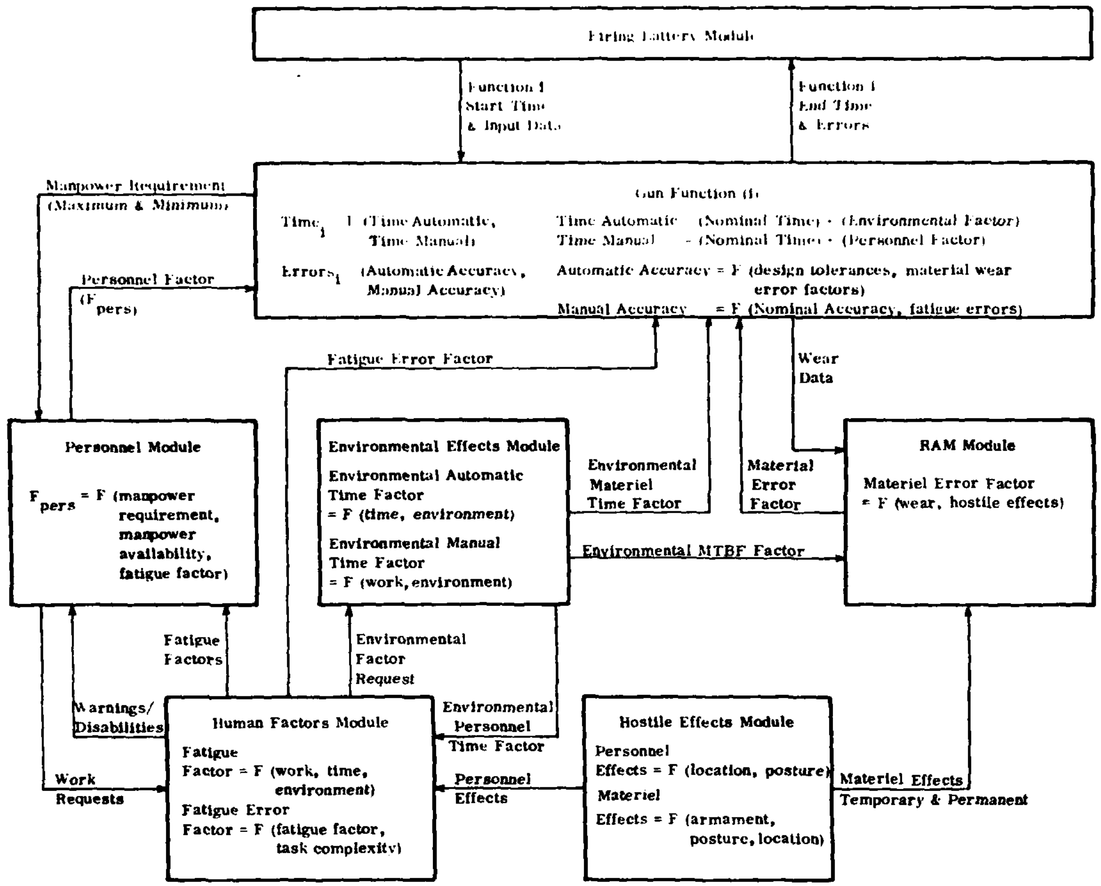



FIGURE 3.3.3.2

INDIVIDUAL GUN FUNCTION INTERFACE DIAGRAM

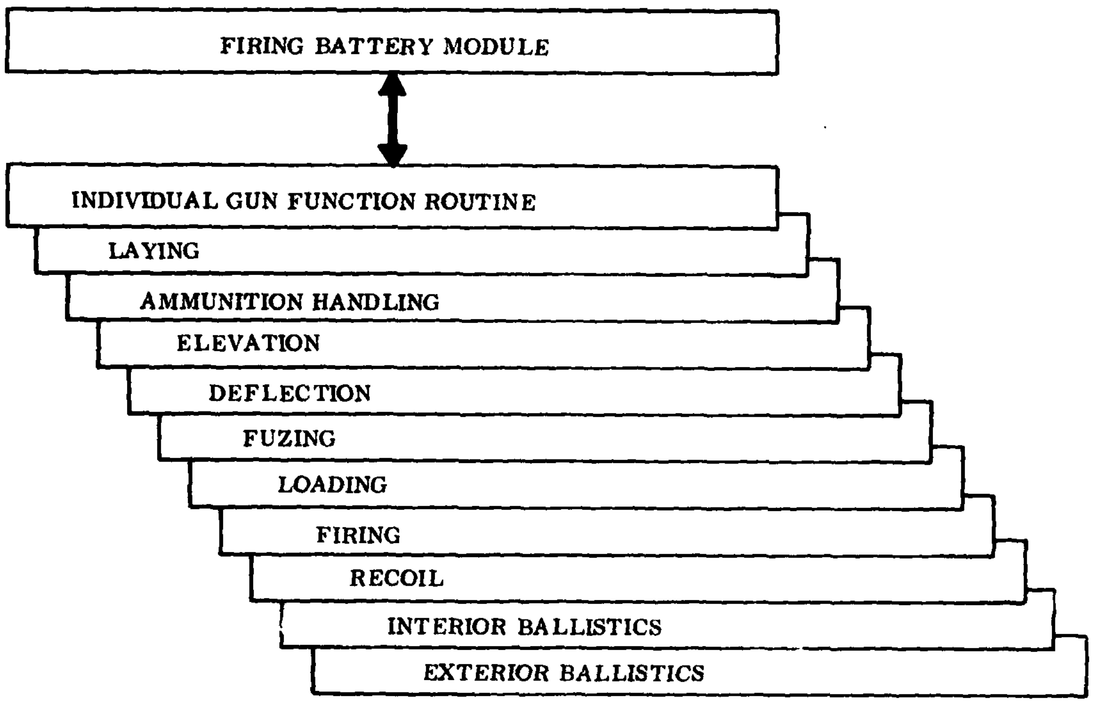



FIGURE 3.3.3.2.1

INDIVIDUAL GUN FUNCTION EXAMPLE SET

technologies may make this possible and the model will be structured to accomodate this in the future. This module will provide the time and errors associated with a particular Fire Direction system as well as the fire solution for the guns. Fire Direction systems which will be considered are the TACFIRE, FADAC and manual procedures. The fire solution provided to the guns will include the Round, Fuze, Charge, Elevation, Deflection and Fuze Setting.

3.3.3.3.1 Inputs and Outputs

The Fire Direction Module will exchange data with other modules as shown in Figure 3.3.3.3 and require initialization of the Fire Mission Queueing Policy.

3.3.3.4 Communications Module

The Communications Module will provide the time and errors involved in all the communications within the battery and externally to the Target Acquisition and $C^3$ modules. This module will therefore know what nets are available; the personnel and equipment requirements for each mode of the net; and account for the effects of hostilities, the environment, personnel and wear upon communication time and accuracy. Each function performed by the battery which requires communications will request message processing from the communications module which will generate the appropriate time and errors or indicate the non-availability of communications for that task.

3.3.3.4.1 Inputs and Outputs

The Communications Module will receive relative distances of each vehicle in the battery which will be used to determine the time and accuracy of communications and whether or not oral communications can serve as a back-up. The interface with other modules are shown in detail in Figure 3.3.3.4.

3.3.3.5 Mobility Module

The Mobility Module will simulate the functions of moving and navigation by calculating the time and accuracy of each move. In order to do this the module will be required to track the location of each vehicle in the battery and be able to calculate relative distances between points. Relative distances will be provided to other modules in the simulation upon request. The calculation of move times will include the effects of the environment, personnel, equipment availability, distance, terrain type and a navigation factor. The navigation factor will be used to generate location errors and effect the move time by considering the factors of fatigue, hostilities, navigation equipment and availability and distance.

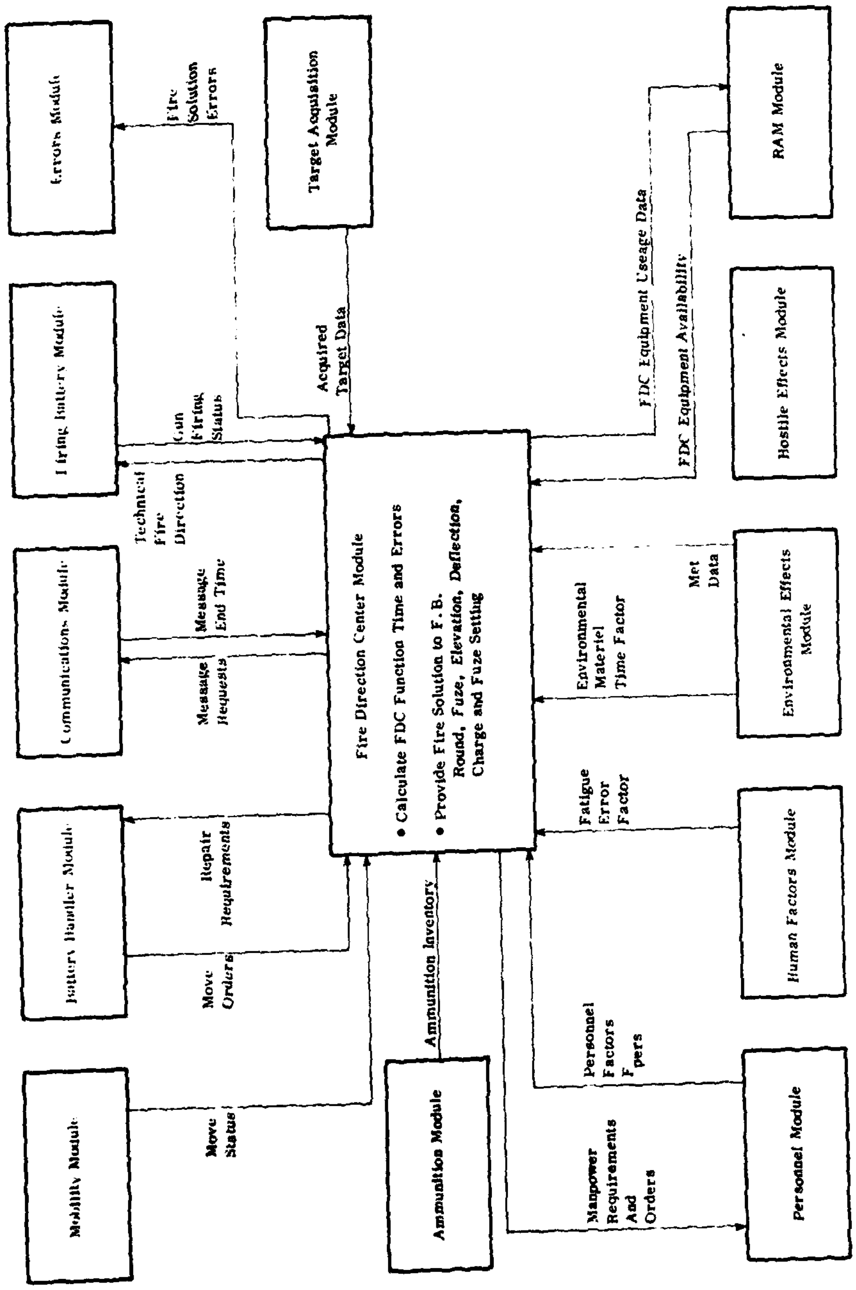



FIGURE 3.3.3.3

FIRE DIRECTION CENTER FUNCTIONAL INTERFACE DIAGRAM

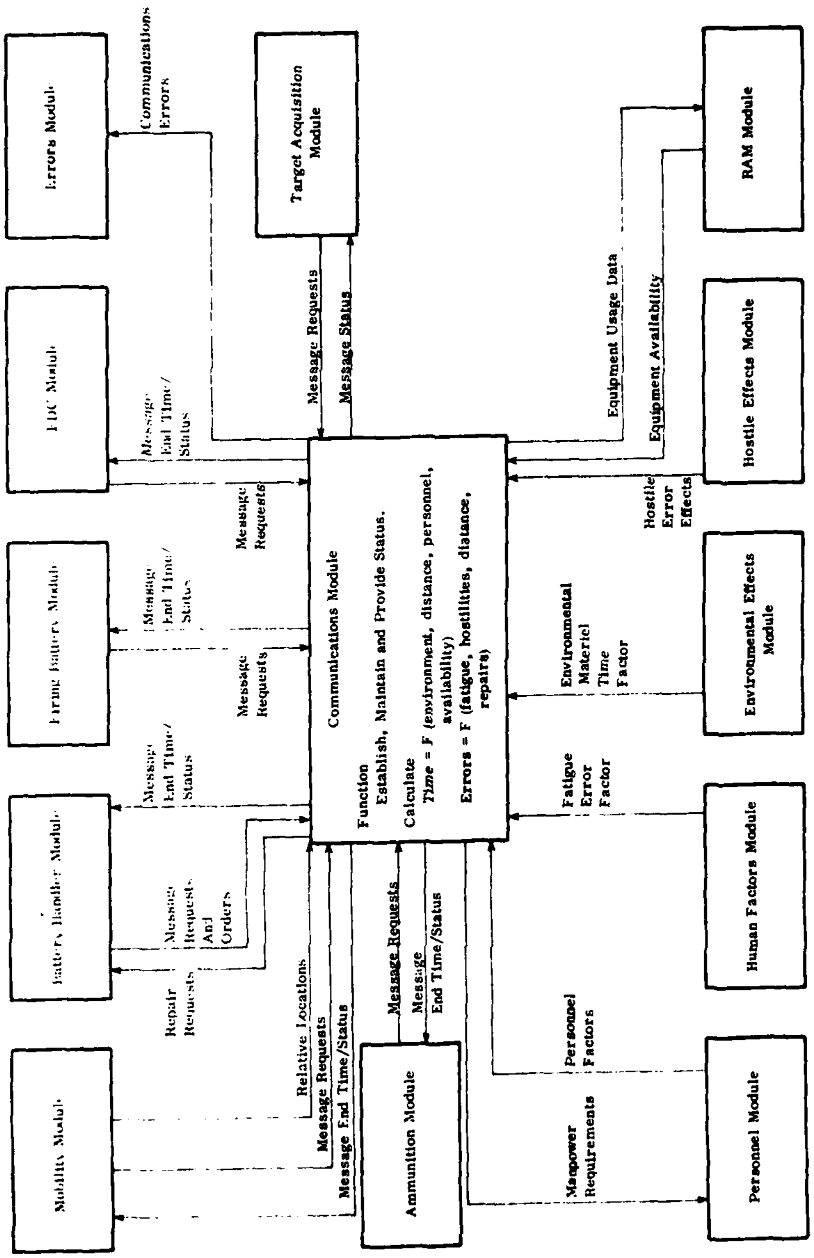



FIGURE 3.3.3.4
COMMUNICATIONS MODULE FUNCTIONAL INTERFACE DIAGRAM

3.3.3.5.1 Inputs and Outputs

The Mobility Module will exchange data with the rest of the simulation as shown in Figure 3.3.3.5. In addition the terrain type and initial positions of the unit will be required as scenario initialization data.

3.3.3.6 Ammunition Module

The primary function of the Ammunition Module is to maintain the inventory of round, charges, and fuzes at the battery and gun levels and to reflect the utilization of time and resources required by the battery to pick up ammunition at the designated supply point, to include travel, and for distribution of ammunition within the battery area. In doing this, consideration will be given to the environment, hostile actions, human factors and RAM-D as external effects. The external ammunition resupply module will account for the ammunition function outside the preview of the battery and will provide replenishment to the designated supply point and the internal Ammunition Module will be responsible for pick up and distribution to the guns. The calculation of ammunition pick up and distribution time will take into consideration the distance, personnel requirements, environment, hostilities and equipment availability. Ammunition will be reordered based upon an inventory policy established by the Battery Handler Module. The policy will determine when, how much, what type and how the ammunition should be distributed within the battery.

3.3.3.6.1 Inputs and Outputs

The Ammunition Module will transfer data with other modules as shown in Figure 3.3.3.6. If initialization data is provided the ammunition module will assume a full load of ammunition, at time zero, in accordance with the mix dictated by the ammunition inventory policy.

3.3.3.7 Personnel Module

This module will account for the assignment of personnel to positions in the battery which may be their primary position or other positions in which they are capable of performing. Initially everyone will be assigned to his primary position and as the effects of the environment, fatigue and hostilities take their toll each person may become permanently or temporarily disabled. Each time a person is disabled or returns to duty a reconstitution of personnel assignments will occur to maximize the unit effectiveness. The marginal degradation of personnel performance will not be accounted for in the personnel module. This will be considered in the Human Factors Module by reducing the efficiency and increasing the errors produced by a person in a particular job as his workload accumulates. There will therefore be extensive exchange of information between the personnel module, the Human Factors Module and the Functional Modules within the battery.

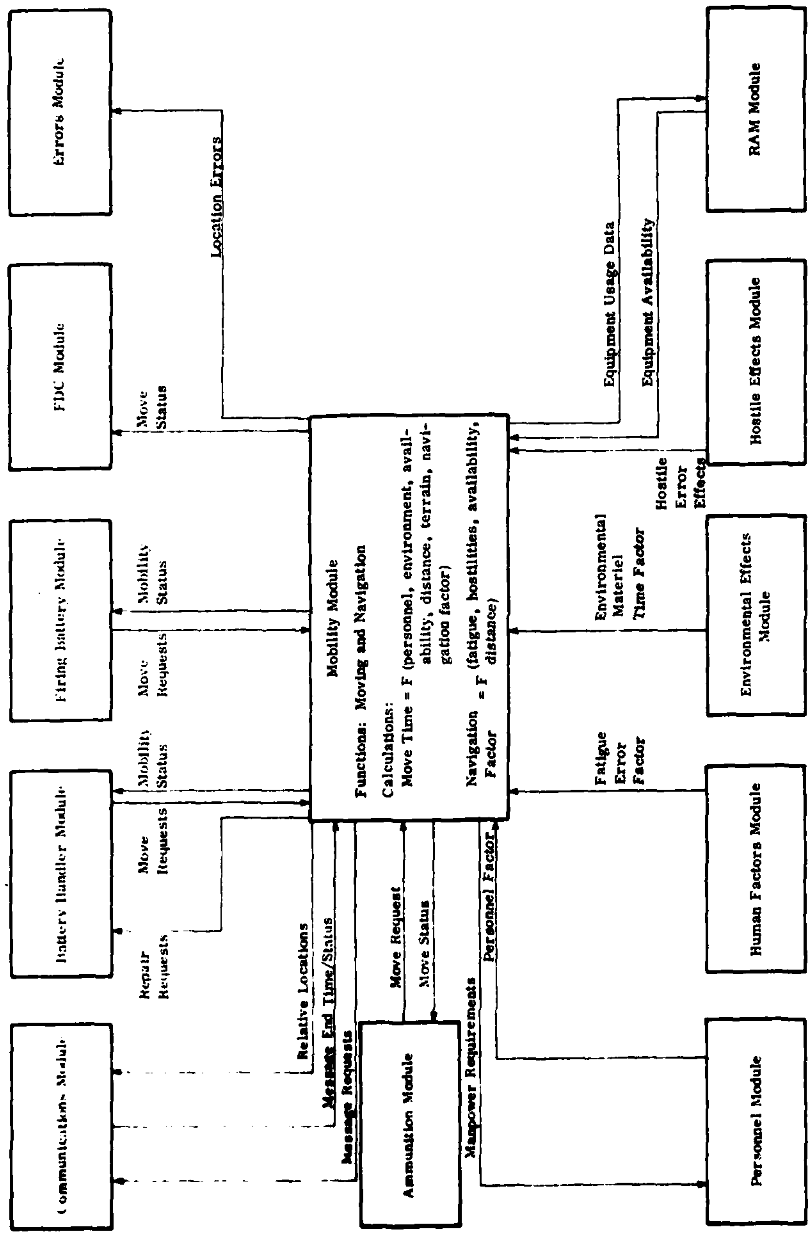



FIGURE 3.3.3.5

MOBILITY MODULE FUNCTIONAL INTERFACE DIAGRAM

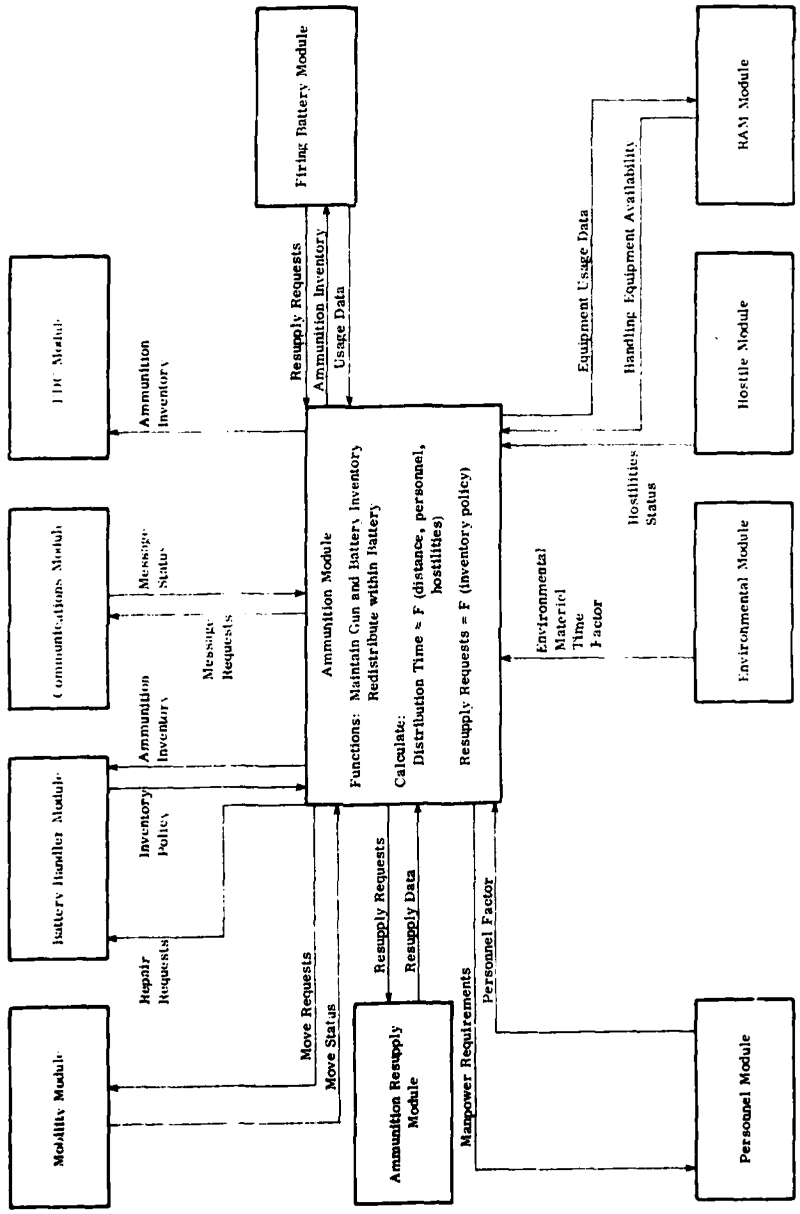



FIGURE 3.3.3.6

AMMUNITION MODULE FUNCTIONAL INTERFACE DIAGRAM

The Personnel Module will calculate a personnel factor as a ratio of, the manpower requested to perform a task, to the available manpower modified by a fatigue factor. This personnel factor will be transferred to the requesting function for use in calculating a function time.

3.3.3.7.1 Inputs and Outputs

The Personnel Module will exchange data with the other modules as shown in Figure 3.3.3.7 and will automatically assume an initial full quota of personnel as required by the data base unless initialized otherwise.

3.3.3.8 Errors Module

The function of the Errors Module will be to collect the technical and human error contributions and transform them into factors which will alter the normal trajectory and terminal performance characteristics of each shot fired. The amount of error in a particular shot or volley will be influenced by terminal guidance or subsequent adjustments by the target acquisition system.

3.3.3.8.1 Inputs and Outputs

The Error Module will exchange data with other program modules as shown in Figure 3.3.3.8. The exclusion of current Met data in a fire solution will cause the effects of that data to be included as an error.

3.3.3.9 Battery Handler Module

This module will simulate the function of the Artillery Battery Headquarters Section which provides the services of mess, supply and maintenance for the unit. The supply function will be simulated in terms of establishing and changing the ammunition inventory policy as demands vary with the battle. The maintenance functions will be simulated by calculating the repair time for organizational level jobs as a function of MTTR, location and personnel. The mess function will not be simulated. Additionally this module will order the movement of the battery from one location to another based upon tactical requirements and the battery dispersion.

3.3.3.9.1. Inputs and Outputs

The Battery Handler Module will interface with other functions of the program as shown in Figure 3.3.3.9 and will require initialization of the ammunition resupply policy, Battery Movement and Dispersion Policy.

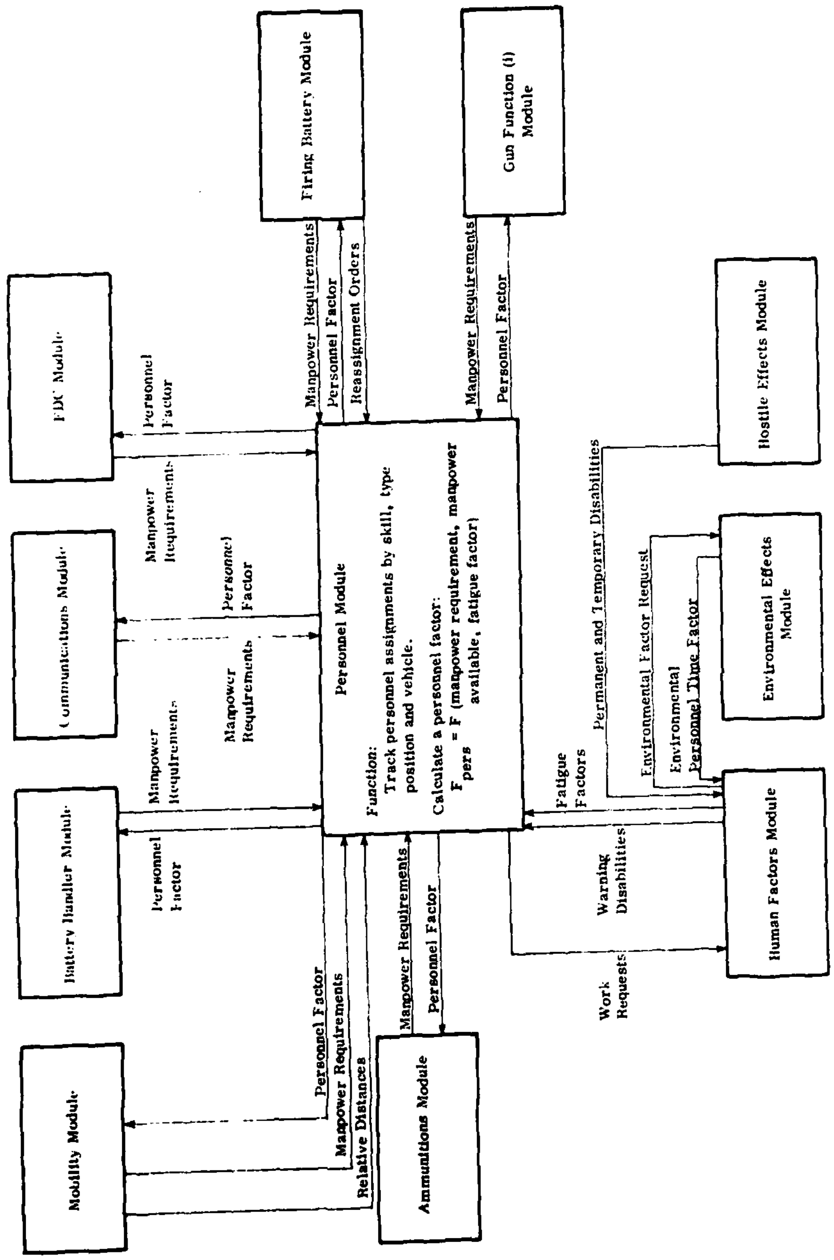



FIGURE 3.3.3.7

PERSONNEL MODULE FUNCTIONAL INTERFACE DIAGRAM

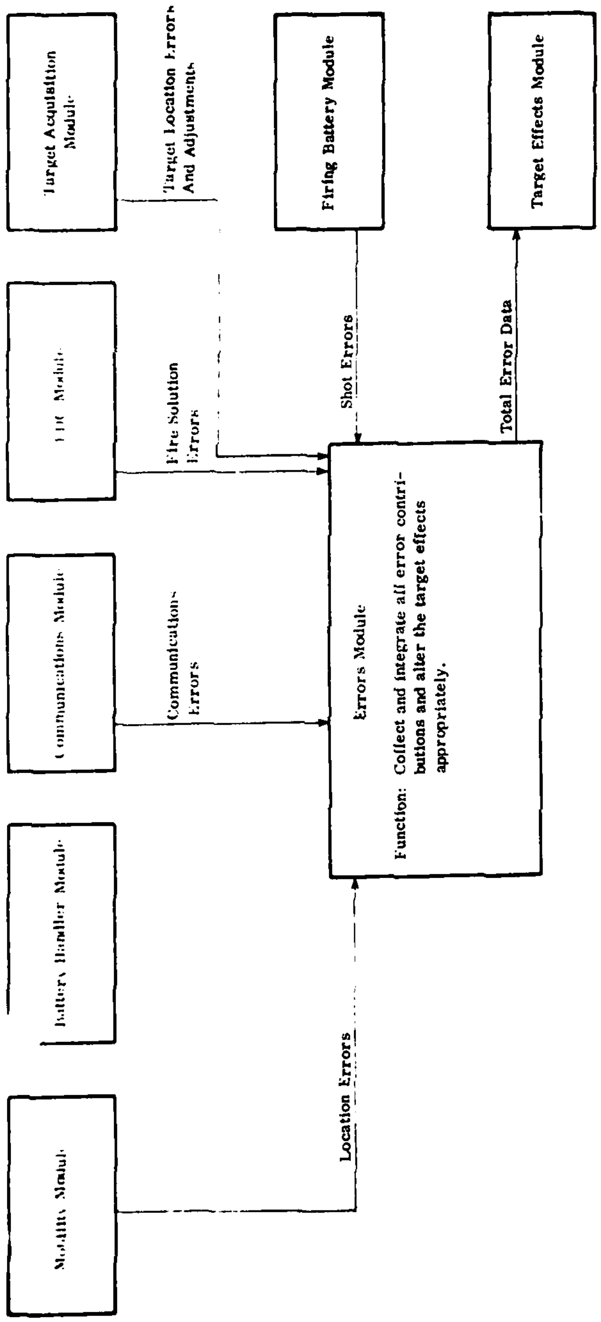



FIGURE 3.3.3.8

ERRORS MODULE FUNCTIONAL INTERFACE DIAGRAM

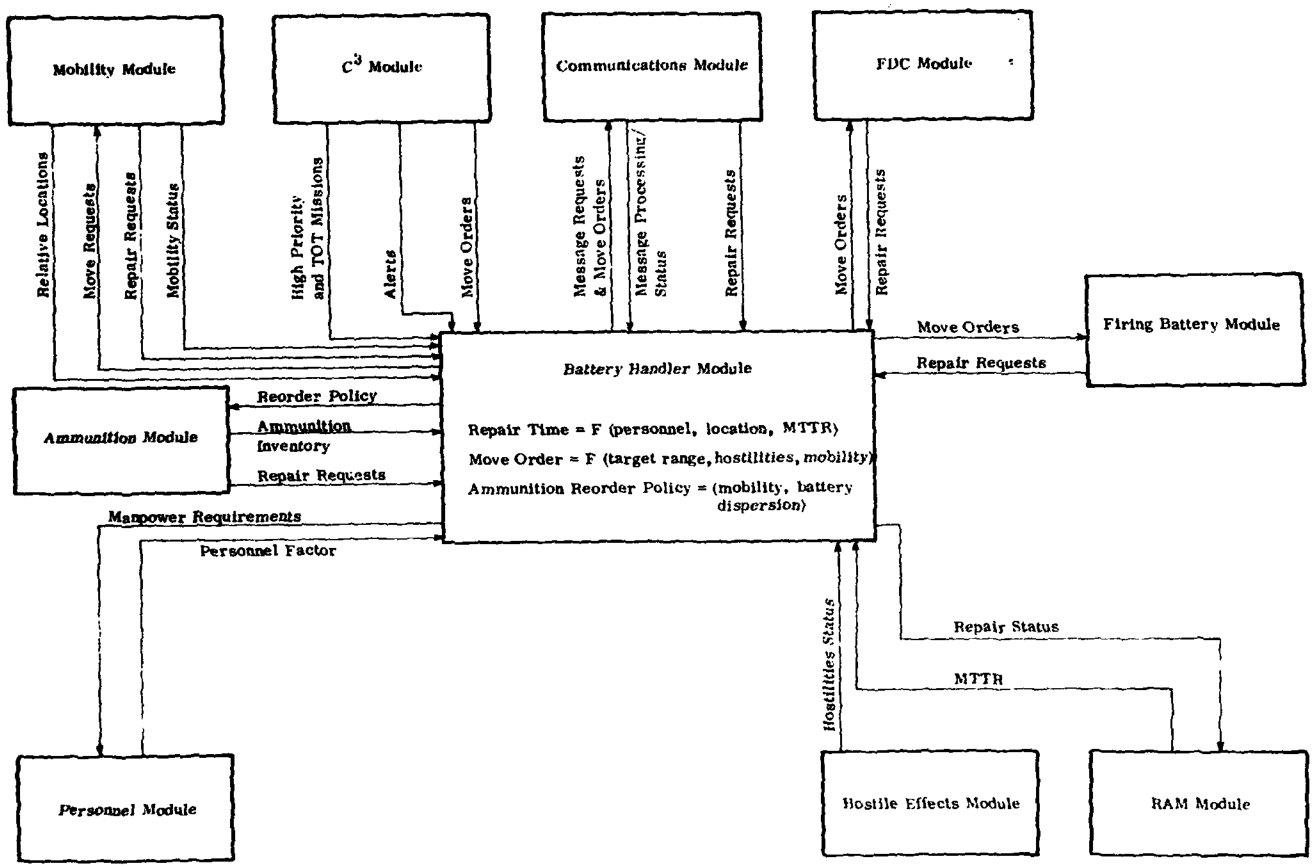



FIGURE 3.3.3.9

BATTERY HANDLER MODULE FUNCTIONAL INTERFACE DIAGRAM

3.3.3.10 Environmental Effects Module

This module will perform the function of providing environmental factors to other modules of the simulation which will be used to adjust cycle time, MTBF, MTTR and accuracy in accordance with the existing environment. The environmental factors will be stored in the engineering data base and retrieved by the Environmental Effects Module in accordance with the prevailing conditions. The environmental conditions considered most important are; temperature precipitation, fog and day/night. For each possible combination of these elements an environmental factor will be required (see paragraph 3.2.4) in the data base. For each function performed by the battery a table of factors will be required to adjust manual cycle times, automatic cycle times, MTFB, MTTR and error rate.

3.3.3.10.1 Inputs and Outputs

The Environmental Effects Module will interface with the other modules of the simulation as shown in Figure 3.3.3.10.1 and will require initialization data to define the conditions during the scenario being played.

3.3.3.11 RAM Module

This module will perform the function of generating failure and repair times for each piece of equipment in the unit. The mobility and communications equipment will be treated as end items but the ammunition and Howitzer shall be treated at the component level. The engineering data base shall contain the actual or estimated MTBF and MTTR figures and the RAM module will use them, as is, or to generate a random failure from an appropriate distribution function. The various equipment using functions shall transfer usage data to the RAM module and it shall return the availability status of the equipment. The MTBF and MTTR figures will be subject to modification by environmental and hostile effects.

3.3.3.11.1 Inputs and Outputs

The RAM Module will exchange data with the other modules as shown in Figure 3.3.3.11.1 and will require initialization input as to the mode of failure and repair generation; namely random or mean value.

3.3.3.12 Human Factors Module

This module will perform the function of decrementing the capability of personnel within the battery to perform whatever function they are assigned to, in accordance with recognized relationships between, time, workload and working environment. This module

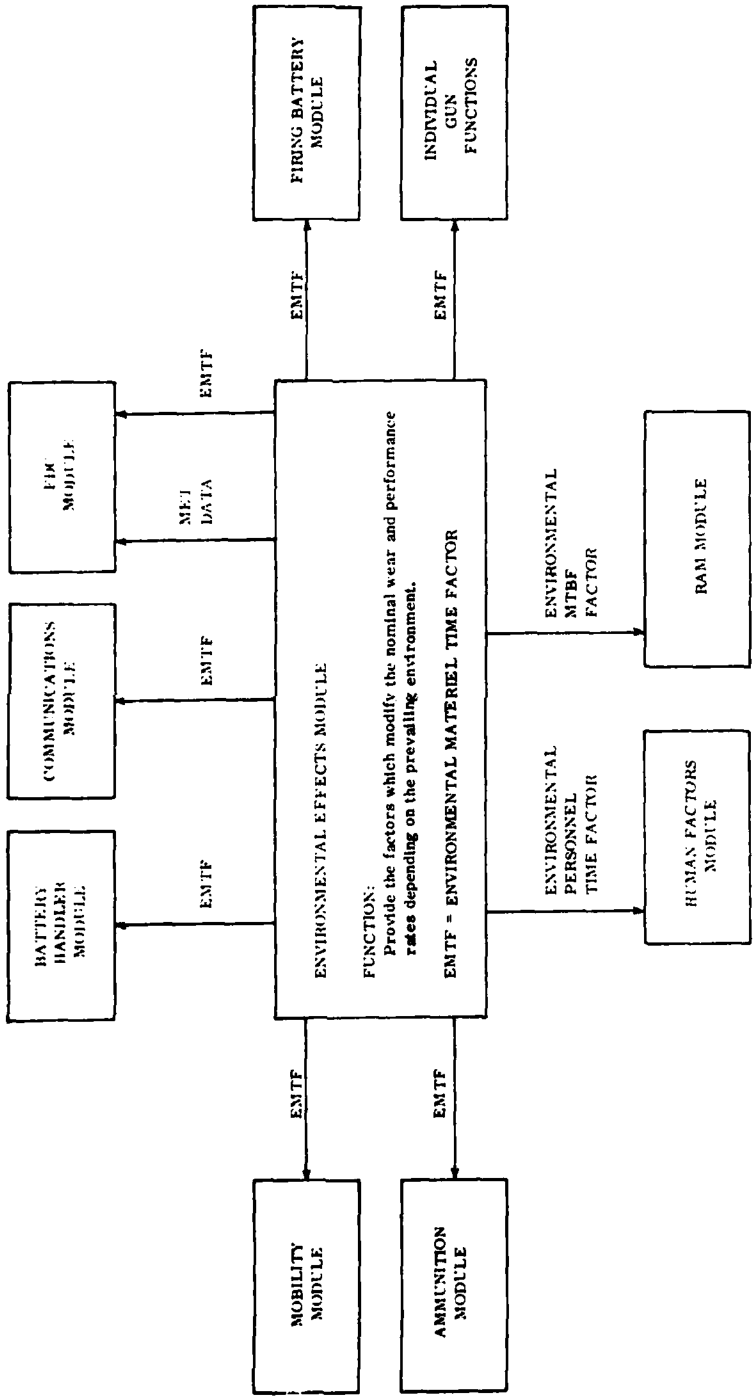



FIGURE 3.3.3.10.1

ENVIRONMENTAL EFFECTS MODULE FUNCTIONAL INTERFACE DIAGRAM

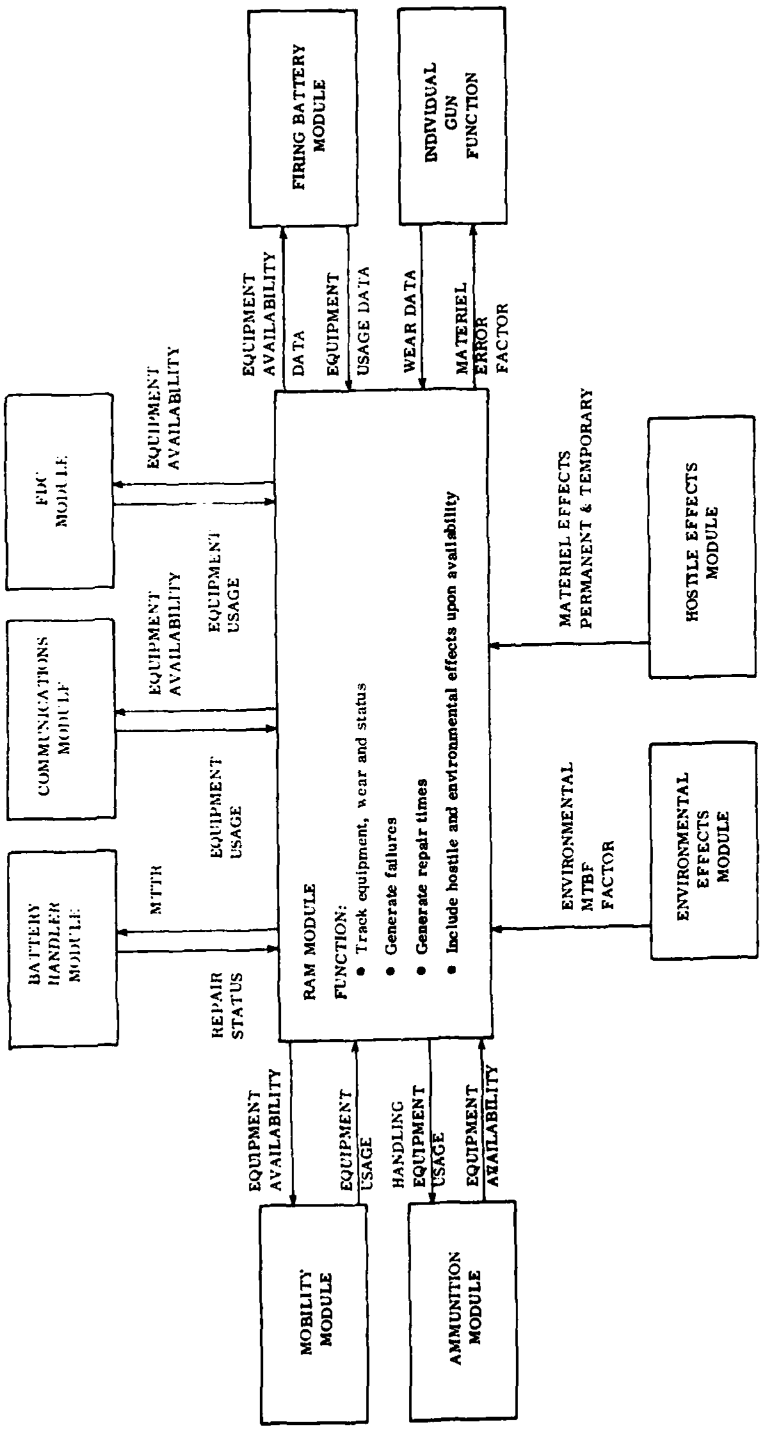



FIGURE 3.3.3.11.1

RAM MODULE FUNCTIONAL INTERFACE DIAGRAM

will indirectly interface with each battery function by receiving requests for individual work from the personnel module and decrementing the type resource according to the work requested and the prevailing environment. When personnel reach a predetermined level of exhaustion a warning will be sent to the personnel module which will attempt a replacement of the individual. If the individual is not replaced before reaching critical exhaustion he will be temporarily disabled via the personnel module.

#### 3.3.3.12.1 Inputs and Outputs

The Human Factors Module will exchange data with other modules as shown in Figure 3.3.3.12.1 and will provide the Fatigue Error Factors directly to the modules shown.

### 3.3.3.13 Hostile Effects Module

The Hostile Effects Module will generate the enemy Counterfire and Electronic jamming which is expected in a given scenario. The effects of Direct attack, Nuclear, Biological and Chemical attacks will not be played in the simulation at this time but the programs will be structured to accommodate their addition in the future. The module will utilize data on probability of detection by the enemy and enemy response time, from the battle level model, to generate the type and times of hostilities. For Electronic Warfare this will result in non-availability of communications, and for counterfire, loss of personnel and equipment, and temporary suppression.

#### 3.3.3.13.1 Inputs and Outputs

The Hostile Effects Module will require inputs from the; Target Effects Module to initiate a firing detection, Communications Module to initiate electronic effects and from the Mobility Module the size of the battery area in square meters to calculate the hostile effects. (See Figure 3.3.3.13.1.)

Outputs will be to the RAM and Personnel Modules in terms of permanent and temporary losses. Initialization input will contain data on the probability of detection and response of enemy hostilities.

### 3.3.3.14 Target Effects Module

This module will use target information from the Target Acquisition Module and shot and error data from the Firing Battery and Errors Modules to calculate the number of kills and length of target suppression caused by each round fired. The calculation of kills will be accomplished in the same manner as is used by the AFSM battle model and suppression of personnel targets will be based on the length of time they are assumed to be in a crouched or prone position.

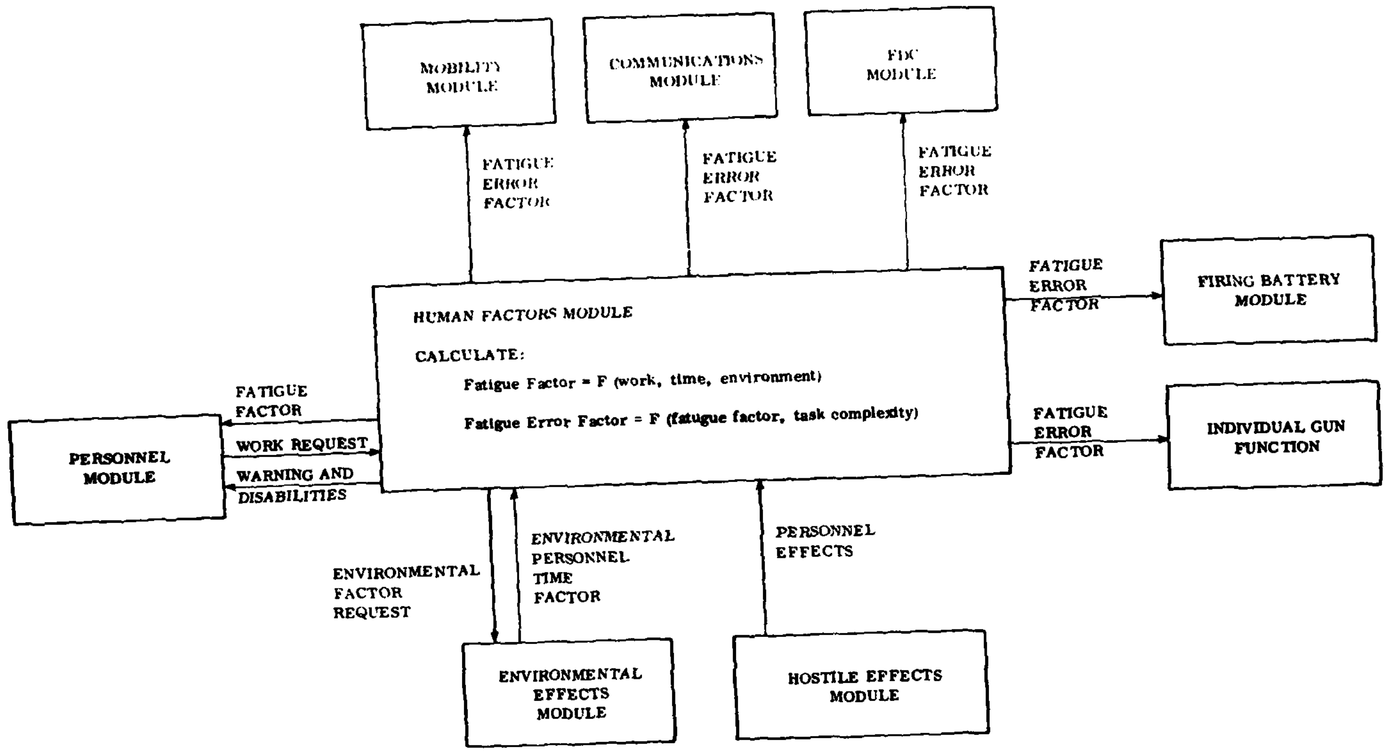



FIGURE 3.3.3.12.1

HUMAN FACTORS MODULE FUNCTIONAL INTERFACE DIAGRAM

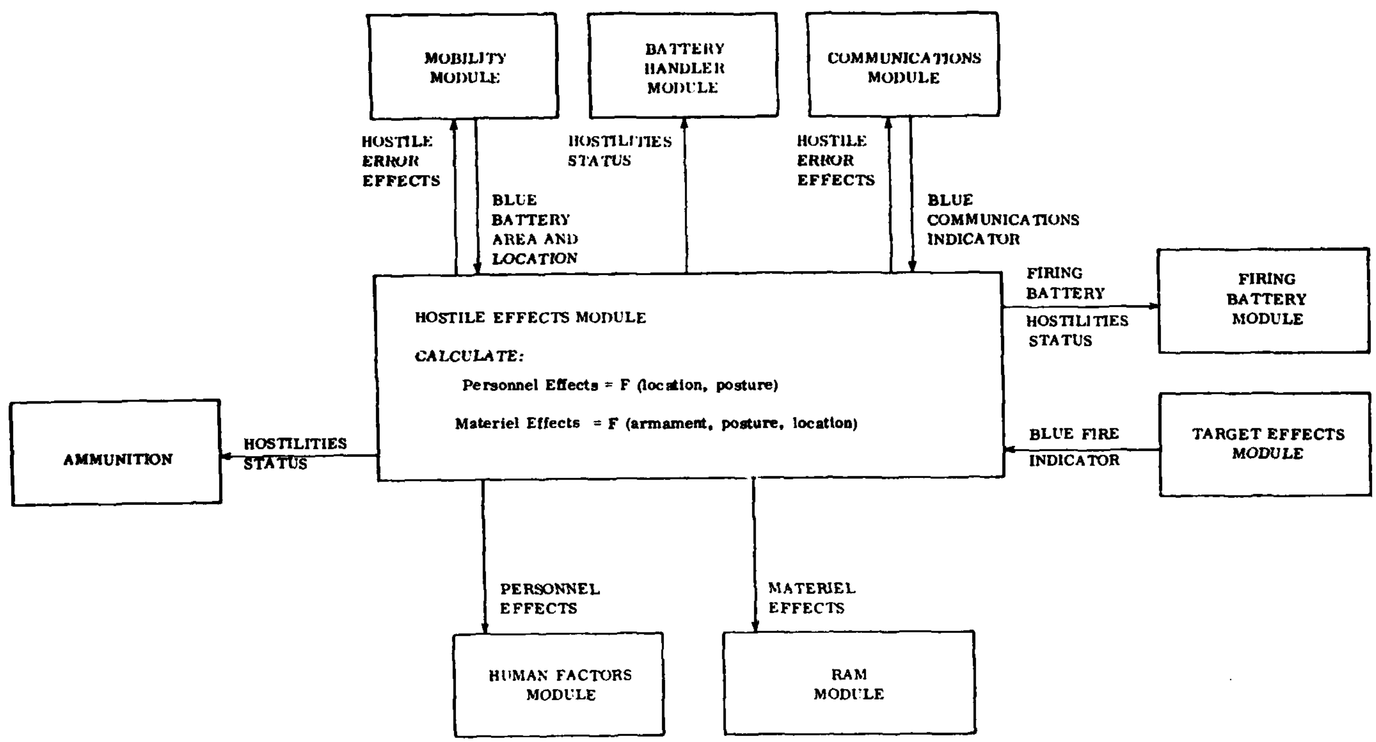



FIGURE 3.3.3.13.1

HOSTILE EFFECTS MODULE FUNCTIONAL INTERFACE DIAGRAM

3.3.3.14.1 Inputs and Outputs

The Target Effects Module will require as input the shot data such a terminal ballistics and time of arrival, and target data such as type, posture, and environment and size. As output the module will provide the number of kills and time of suppression of both personnel and material. (See Figure 3.3.3.14.1.)

3.3.3.15 Target Acquisition

The Target Acquisition Module will emulate the function of providing to the battery; target information, requests for fire and adjustment of fire as it is performed by the various target acquisition systems and forward observation teams in the battle scenario. The list of targets will be generated by the battle model and provided to the Target Acquisition Module as they occurred in the battle simulation terms of time, location and importance. The module will in turn provide the targets to the battery utilizing the appropriate means of communication and send to the Errors Module typical target location errors which will be associated with that particular target location device. The battery will be provided, either a prescribed number of rounds to fire or subsequent adjustments and end of mission commands.

3.3.3.15.1 Inputs and Outputs

The Target Acquisition Module will require initial input from the battle model in the form of target information such as; target type, size, location, environment type rounds requested, type mission requested, type of acquisition device and target priority. Internally the module will receive message processing input and send target information and location errors to the Fire Direction and Errors Modules. (See Figure 3.3.3.15.1.)

3.3.3.16 $C^3$ Module

This module will simulate the effects that higher echelons of command have upon the artillery battery. It will essentially be a buffer containing high priority tactical data to be injected into the simulation at given times. Examples of this type of data are, move orders, high priority fire missions, time on target fire missions and tactical alerts and warnings. This data will be derived from the battle model or included at user discretion to assess the impact upon system performance and effectiveness.

3.3.3.16.1 Inputs and Outputs

Inputs to the $C^3$ Module will be battle scenario or user generated events which will simulate the input from higher echelons to the battery. All outputs of the $C^3$ module will go to the Battery Handler Module. (See Figure 3.3.3.16.1.)

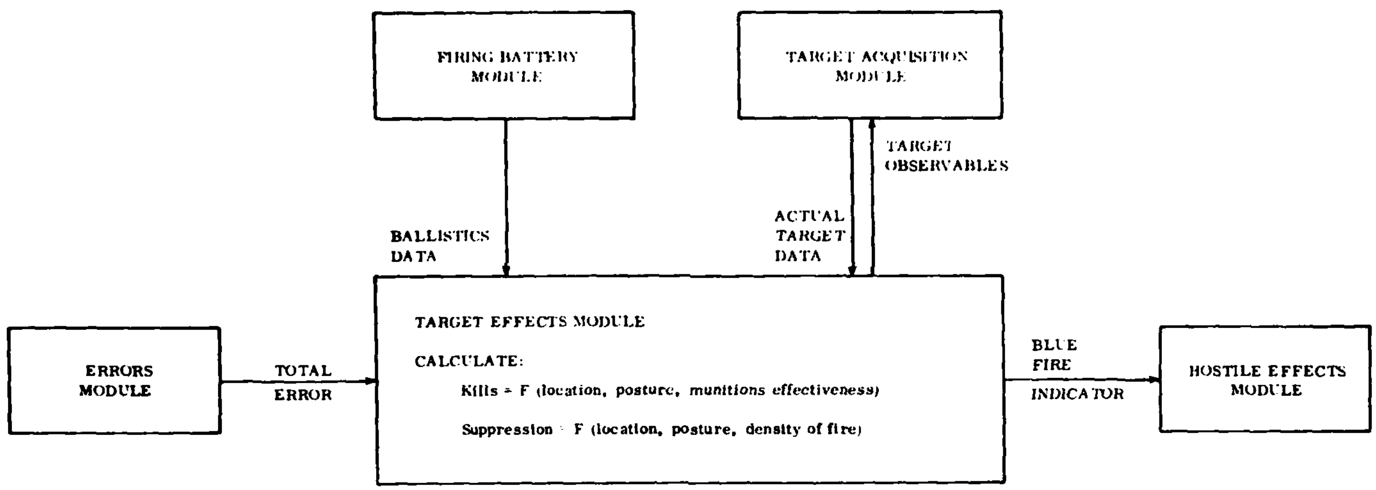



FIGURE 3.3.3.14.1

TARGET EFFECTS MODULE FUNCTIONAL INTERFACE DIAGRAM

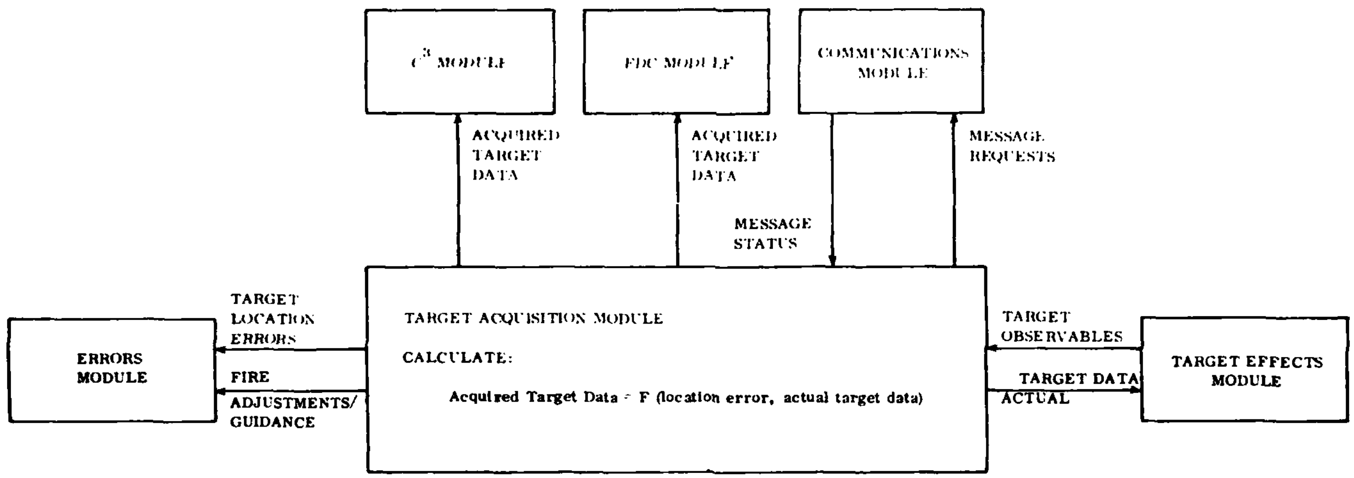



FIGURE 3.3.3.15.1

TARGET ACQUISITION MODULE FUNCTIONAL INTERFACE DESIGN

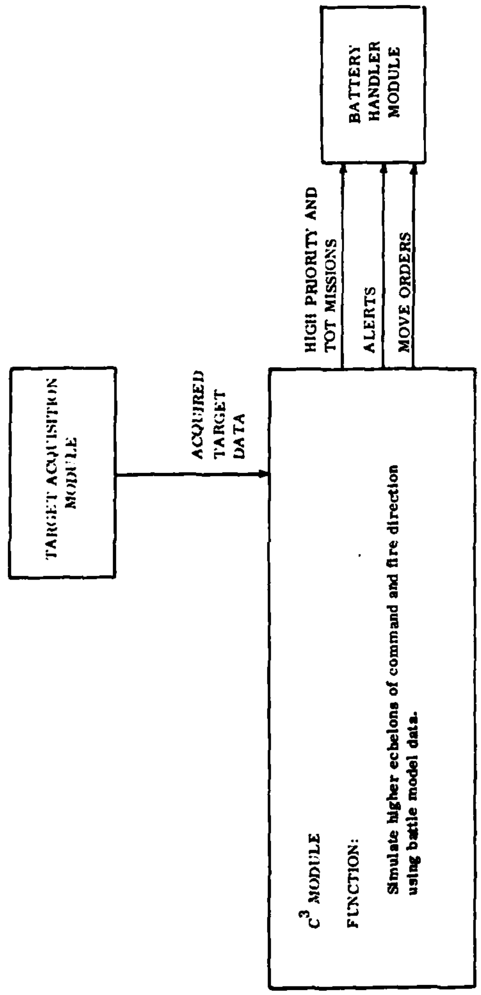



FIGURE 3.3.3.16.1

$C^3$ MODULE FUNCTIONAL INTERFACE DIAGRAM

3.3.3.17 Ammunition Resupply Module

The Ammunition Resupply Module will simulate the level of ammunition inventory at the battery resupply point. The module will essentially constrain the rate at which the battery vehicles can receive ammunition and the constraint will come from either the battle model or other ammunition resupply models.

3.3.3.17.1 Inputs and Outputs

Inputs to the Ammunition Resupply Module will be the constraint parameters from the ARRADCOM Resupply Models or the battle model. Outputs will be the level of inventory of the requested ammunition which will go to the battery Ammunition Module. (See Figure 3.3.3.17.1.)

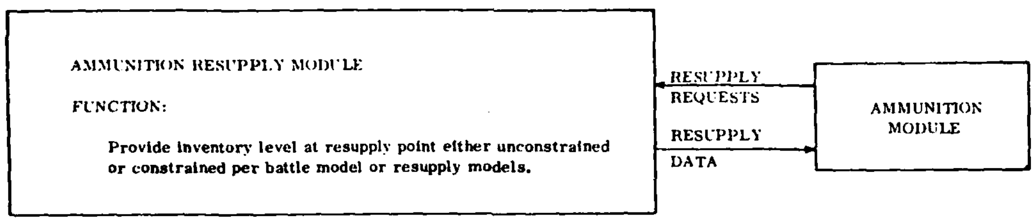



FIGURE 3.3.3.17.1

AMMUNITION RESUPPLY FUNCTIONAL INTERFACE DIAGRAM

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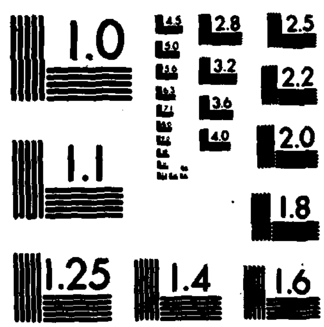


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